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PUBLIC HEALTH.

TENTH REPORT

OF

THE MEDICAL OFFICER OF THE PRIVY COUNCIL.

THE PROPERTY OF THE YORK HOSPITAL
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JAN 1867

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TO THE LORDS OF HER MAJESTY'S MOST HONORABLE PRIVY COUNCIL.

My Lords,

In obedience to the Public Health Act, 1858, I have the honour of herewith submitting to Your Lordships, for presentation to Parliament, my Report of the proceedings which Your Lordships under that Act directed to be taken during the year 1867.

I am, my Lords,
Your Lordships' obedient servant,
JOHN SIMON.

Medical Department of the Council Office,
8, Richmond Terrace, S.W.;
March 31st, 1868.

26132

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MEDICAL OFFICER'S REPORT.

I.—The Administration of the Diseases Prevention Act.

Diseases Prevention Act.

The Diseases Prevention Act, which in the summer of 1866 had been put in force by Her Majesty's Government on account of the diffusion of Asiatic Cholera in England, was kept in operation throughout the whole year 1867 by successive Acts of the same authority; and my Lords of the Council, on each of the half-yearly occasions when the Act was ordered to continue in force, provided that also the Medical Relief Regulations of 1866 (as given in App. No. 5 of my last annual Report) should continue. Those regulations, for their first issue, had been carefully so constructed that their renewal from time to time should not make any further claim on local authorities for trouble or expense, except in so far as new outbreaks of cholera might arise; and, subject to this condition, it appeared better that the Regulations should continue in force, ready for immediate application to any such outbreak, than that risk should be run of emergencies perhaps to arise after their lapse. Fortunately the year 1867 passed without any noticeable repetition of the epidemic experience of 1866. In this state of the case a further continuance of the Regulations seemed unnecessary, and at the date of my present writing the Diseases Prevention Act has ceased to be in force.

II. The Regulation and Superintendence of Public Vaccination.

Vaccination

In 1867, as in previous years, my Lords superintended the Public Vaccination of England; including (1) the proceedings of local authorities and officers in that matter; and (2) the establishment by which the national supply of vaccine lymph is maintained; and (3) the arrangements which give effect to the Order of Council regulating the qualifications of public vaccinators.

1. *District-Inspections, and Awards to Public Vaccinators*

District Inspections, and Awards to Vaccinators.

In superintendence of local proceedings, my Lords during the year provided for the inspection of 1,651 vaccination-districts comprised in 336 different unions or parishes. The system, described in my last report, for awarding to meritorious public vaccinators certain payments in addition to those which are claimable by them from their respective boards of guardians—payments, namely, out of a special fund granted by Parliament for this purpose, had now come fully into operation: not indeed hitherto with the definite statutory sanction (30 & 31 Vict. c. 84) which at present regulates it, but with provisional authorization from the

Treasury: and on this system my Lords during the year distributed 1,824*l.* among various vaccinators of England. The number of vaccinators to whom gratuities were given was 231; namely, 61 who received first-class, and 170 who received second-class, gratuities. The gratuities of each class differed of course very considerably in money-value in different vaccination-districts, just as the several contract-earnings differed. Where a public vaccinator was having so few vaccinations as to be only earning from his board of guardians some 20*s.* or 30*s.* a year, the supplementary payment by the Privy Council was necessarily quite insignificant as money, and, except that it implied an honorable recognition of services, might not have seemed worth the trouble of formal transmission and acknowledgment; but, on the other hand, in many cases the payments were such as probably to be in themselves welcome additions to the often scanty stipends of the recipients. The largest aggregate payment of the year (a second-class gratuity on 2,021 vaccinations) was 67*l.* 7*s.* 4*d.*; the smallest (a second-class gratuity on 23 vaccinations) was only 15*s.* 4*d.* It may be observed that if these had been first-class gratuities, as I hope they may be in future inspections, the respective amounts would have been 101*l.* 1*s.* and 1*l.* 3*s.*

My Lords during the year had occasion to correspond specially with the guardians of the unions of Tisbury, Sheppey, Dartford, Hendon and Lewisham, with regard to outbreaks of smallpox reported in those jurisdictions respectively; and in one of these cases (that of Sheppey) local inquiry by one of their Lordships' inspectors was made.

2. *Supply of Vaccine Lymph.*

Vaccine Lymph.

In answer to 13,240 applications made during the year for vaccine lymph, there were supplied under their Lordships' orders 131,480 charged ivory points, 2,460 charged squares of glass, and 8,167 charged capillary tubes. Particulars as to the sources whence this lymph was derived are given in Appendix No. 1. Of the 13,240 applications, in answer to which lymph was given, 10,434 came from medical practitioners (including 1,429 poor law medical officers) in England and Wales; 1,633 from Ireland, and 455 from Scotland; 428 from the army; 116 from the navy and emigration-department; 119 from colonies, and 55 from diplomatic and other foreign services.

My Lords, as usual, took means during the year to satisfy themselves as to the undiminished efficiency of the lymph which is supplied under their directions. The only change which took place in 1867 in regard of the London stations of the National Vaccine Establishment consisted in the appointment of Mr. W. E. G. Pearse to the Tottenham Court Chapel station in place of Mr. George Simpson, deceased.

3. *Educational Vaccinating Stations.*

Educational Stations.

Of the twenty-one stations which are sources of national lymph supply, thirteen are used as educational stations under their

Lordships' Order of December 1st, 1859, concerning the qualification of contractors for public vaccination. And Dr. Seaton, while inspecting these stations in reference to their stock of lymph, inspected them also in reference to their educational business. In this second respect, as in the former one, his report was entirely satisfactory.

Medical Officer's Report.

III. Inquiries and Actions in other Matters.

The proceedings of the Lords of the Council in 1867, in that general relation to the interests of the Public Health in which the Act of 1858 appoints their Lordships to stand, were, as usually, of two sorts. In the first place there were proceedings of an essentially *occasional* sort, with reference to particular outbreaks or threatenings of disease during the year, or to particular complaints which had been made of dangerous nuisance in various parts of the country; and in the second place, there were proceedings of an essentially *systematic* sort, forming part of a plan of work which goes on connectedly from year to year. And of these two sorts of proceedings the following were the main facts.

Other Inquiries: occasional and systematic.

1. *Occasional Proceedings.*

On numerous particular occasions where complaints of the state of districts were made, or where outbreaks of endemic disease had occurred or were apprehended, my Lords during the year had correspondence, which was for the most part with local authorities, with regard to the administration of the Nuisances Removal and other common sanitary Acts. The authorities thus corresponded with were 113; including the 76 nuisance authorities of Wales, 10 of the vestries and district boards of the metropolis, 10 boards under the Local Government Act, and 14 boards of guardians.

Occasional Inquiries.

In three of these cases, namely, in regard of Winterton in Lincolnshire, Guildford in Surrey, and Terling in Essex, local inquiry by an Inspector under their Lordships' direction was deemed necessary: these being the chief cases in which in 1867 a prevalence of typhoid fever constituted the matter of complaint. All three cases were in substance such as I have again and again reported on, as illustrations of excremental poisoning; and this filthiest chapter in the history of our pestilences is one which I would gladly consider myself exonerated from re-opening on the present occasion. As regards those for whom primarily my Reports are written—the makers and administrators and officers of sanitary law in England, it may seem superfluous that I again proceed to illustrate in some detail the dependence of typhoid fever on conditions which it is disgusting to specifiy. But while the evil continues—while annually in England some fifteen to twenty thousand persons are killed, and perhaps twenty times that number grievously sickened and endangered, by a disease which solely prevails through the pollution of atmosphere and drinking-water with excrement, the subject

could not properly be set aside, unless Legislature and Government had already quite exhausted their powers in fruitless endeavours against the evil. I venture to believe that such is not the case; and purposing presently to invite judgment on this question, I shall briefly state here the leading facts of each of the three epidemics, and for further details append the reports of the inspectors who made the local investigations. See App. Nos. 2, 3, 4.

Typhoid fever in Winterton.

i. The little town of WINTERTON in Lincolnshire, having a population of about 1,800 persons, had for the last seven years been almost always suffering more or less from the presence of typhoid fever, and for the last two or three years the disease had been of great local importance. Sometimes it was more in one part of the town, sometimes more in another. In 1865–6 it particularly attacked a group of 35 houses at the west end of the town; and here, within the twelve months, out of 145 inhabitants 100 contracted the fever, and 17 died of it; or, in other words, those 145 inhabitants suffered in that year from the one preventable disease as many deaths as a population *seven times as great*, in fair sanitary circumstances, is expected to suffer *from all diseases and accidents put together*. Early in 1867 typhoid fever was again prevailing in large proportions in Winterton, but chiefly in another part of the town; and when their Lordships' inspector was there in April, there had been 55 new cases, and among them already 6 deaths. The cause of all this terrible sickness and mortality was of course evident to their Lordships' inspector at a glance. It was the merest question of filth. "The epidemic prevalence of fever in Winterton," he writes, "is undoubtedly to be ascribed to the disgraceful state of the privies, cesspools, ashpits, and wells. . . . . Given, the existence of typhoid fever in a town, it is hardly possible to conceive conditions more favourable for its spread than these existing at Winterton." Extracts which I append from his Report (App. No. 2) contain copious details in support of the above conclusion. The conditions described are such as probably even the swine in the town may have suffered from; and it deserves notice that the scene of this disgraceful sanitary neglect was a town which four years previously had adopted the Local Government Act.

Typhoid fever in Guildford.

ii. The epidemic of typhoid fever at GUILDFORD was peculiarly instructive. Guildford is not ordinarily quite exempt from typhoid fever; and during the first twenty-eight days of last August 10 such cases had been seen scattered about in the town; when suddenly within the next thirty-three days there had arisen fully 250 cases of the disease, and of this large number 150 had arisen within a fortnight. The distribution of the disease, especially during the first fortnight of the epidemic, so nearly corresponded in area with a particular section of the public water-supply of the town as to raise the strongest suspicions that this section of the water-supply was at fault. And eventually these suspicions became a certainty. First, namely, it was shown that on one particular day in August (about ten days before the beginning of the outbreak) 330 of the 1,675 houses of Guildford had

exceptionally received their water from a certain high-service reservoir which had been previously filled from a new well; and that the persons residing in or frequenting these 330 houses constituted the part of the population on which the epidemic influence had almost exclusively fallen. Subsequent chemical examination of the water of the new well detected in it the products of organic decomposition; and examination of the local circumstances showed, but too unquestionably, whence the decomposing organic matter had been derived. The new well, no one could doubt, was most dangerously situated: in the porous and fissured chalk-stratum, it was within ten feet of various sewers; one of which indeed was traversed, as a short cut, by the iron delivery-pipe of the high service. And when, after the epidemic, this reckless confusion of sewer and water-works was dissected, the state of things found at the spot, was reported to us in the following terms by Mr. Taylor, one of the Poor Law Medical Officers of the town:—"The engineers employed in the repairs of the steam engine noticed some exudation on the wall of the engine house next the alley where the sewer runs, and the pit of the fly-wheel contained a notable quantity of the same. As the exudation had the smell of sewage, the ground was opened in the alley at a point adjacent to the engine house. The sewer was found leaking in various places, and the soil between it and the wall of the engine-house was saturated with sewage, of which as much appeared to run outside as inside the sewer. This was found to be an old-fashioned 12-inch drain constructed with red unglazed gutter tiles, with butt joints and common mortar. The tiles forming the lower half of the cylinder were in places completely worn away, and at one point several feet of them were missing, and the upper tiles had fallen in upon the soil below. All the joints gave exit to water, and the ground was a quagmire of filth beneath and on each side. Dark coloured fetid slush had to be dug out and removed in baskets, making the men vomit who were employed in the work."—There of course could not be any reasonable doubt but that the passage of this filth into the well, from which the high-service reservoir was filled, had been the cause of the epidemic. Mr. Taylor further informed us that the whole number of deaths from fever up to the end of the epidemic was 21, including three or four who died in other districts after removal from Guildford; and that he roughly computed the total number of cases of fever from August to December at 500.

Typhoid fever in Terling.

iii. The epidemic at Terling, in Essex, was one of extraordinary dimensions. In that village of only 900 inhabitants, and for the most part within a period of two months, fully 300 persons were attacked with typhoid fever, and 41 of the number died. That is to say, the one preventable disease killed in that short time a larger proportion of the population than all causes of death put together ought to have killed there in two years. The conditions which rendered possible this most calamitous visitation of disease were, as in all our other experience, conditions of local filth. At Terling such conditions were at their worst. Round what pretends to be the house-accommodation of the tillers of the soil in Terling

MEDICAL OFFICER'S REPORT.

(a scanty overcrowded supply of dwellings of the meanest description) every possible source of pollution for air and water was accumulated; the peculiarly porous soil which underlay all this filth was of course continuously absorbing it; the water-supply of the population was derived from wells, most of them sunk in that excrement-sodden sponge of earth; some ten days before the outbreak of the fever, after an extraordinary period of drought, a sudden great rise in the water-level of the wells was observed; and this of course denoted a long-delayed scouring of that foulest soil into the water-supply of the now poisoned population. The epidemic incidentally deserved and received, for ulterior reasons, very particular scientific investigation; but my reference to it in this place is exclusively for practical purposes. The filth which did so enormous an injury to human life, existed under definite legal responsibility. The Nuisance Authority of the place (the Board of Guardians of the Witham Union) had most grossly neglected its duty. My Lords, in deference to what they believe to be the intentions of the Legislature, felt themselves bound to allow the Local Authority very ample opportunity even for tardy action; but when it became obvious to them that no sufficient use was being made of this opportunity, and that to spend further time in remonstrating with the Board of Guardians would not consist with due regard to human life in the district, their Lordships judged it necessary to move Mr. Secretary Hardy to put in force the compulsory provisions (Sections 16 and 49) of the Sanitary Act, 1866.

State of the law as to compensation of persons injured under the Nuisances Acts, &c.

I have already intimated that except for an immediate practical purpose I should not have thought it necessary again to give in one of my annual reports such extremely disgusting details as are here stated (partly in my last paragraphs, and still more fully in the appended reports of the inspectors) with regard to the local circumstances of our three chief fever-epidemics of 1867. But I have to raise a question which seems to me of the very utmost importance for the future sanitary progress of the country. And for the purpose of my argument I must refer to those three cases as types. They illustrate perfectly, but without any trace of exaggeration, the circumstances under which alone Typhoid Fever is empowered annually to kill so many thousands of our population, and to prostrate for months at a time so many scores of other thousands. Nor is this all. When cholera from time to time is among us, and its victims, during the short while of its prevalence, are counted in quick-succeeding thousands, like the slain and wounded of great battles, the circumstances of that pestilence are the same. The laws of its contagion in this country are substantially the laws of the fever-contagion: always there is the one story of filth: "excrement-sodden earth, excrement-reeking air, excrement-tainted water, these are for us the Causes of Cholera."* Now the point which I to some extent raised in my last report, as concerning the legal responsibilities of malfeasant water companies, is one to

* Ninth report, p. 33.

which I cannot but revert in connexion with our late Guildford experience: though now under slightly different circumstances, for on this particular occasion, as it happens, the water was purveyed by a local board. But the question which I am anxious now to raise is of very much larger scope than that formerly touched upon. It seems to me that the time has now come, when, not only as regards commercial water-companies, but also as regards local sanitary authorities, certain sorts of malfeasance should involve an obvious and unquestionable liability to pay pecuniary damages to persons whom the malfeasance has injured. I am not qualified to say that some liability to this effect may not at present be latent in our law: but I believe that at least it has never hitherto been judicially defined or affirmed: and it is evident that in this state of the case years may elapse before any aggrieved person, unless unusually rich and public-spirited, will be willing to incur considerable legal costs in testing his so doubtful claim to redress. I venture to submit that in this point of view the sanitary rights of the public are but very imperfectly secured, and that explicit legislation in the matter seems to me greatly to be desired. The effect of such legislation would be that what I may call *the fixed and finished parts* of sanitary science, as distinguished from those which are in any degree uncertain and speculative, would very rapidly become ordinary rules of conduct in civil life. In cases of alleged sanitary wrong, courts of law would have the facts in evidence before them; and judges and juries would determine whether wrong (in legal sense) had been done, and would assess the pecuniary damages in proportion. I would invite attention, in this point of view, to the three cases which are above reported. Apart from legal subtilties, on which I am not competent to speak, it seems that the distribution of fouled water by the Guildford Board (regarded for the moment as a water-company) is as proper a case for judge and jury, on action for damages by any of the 500 people who had typhoid fever in the town, as any case in which a railway-collision brings some scores of passengers into harm; and the fact (as I believe it to be) that these water purveyors gave typhoid fever to their customers would be brought home to their consciences, and be suggested as a warning to other water-purveyors, in a far more conclusive and effective manner by such legal proceedings as I suggest, than it can be by any departmental statistics and remonstrances. Again, as regards the epidemics at Winterton and Terling:—under 29 & 30 Vict., c. 90, sect. 20, it is expressly the duty of certain local authorities that they make from time to time (personally or by their officers) inspection of their districts, with a view to ascertain what nuisances exist calling for abatement, and that they enforce, in regard of such nuisances, the provisions of the Nuisance Removal Acts. If cases like those of Winterton and Terling were before a court of law, and the propositions were affirmed (as I apprehend they unquestionably must be) that the duty of the authority had been utterly neglected, and that the sufferings of the population, or of parts of the population, had resulted from the neglect, "injury," in that legal sense which implies a title to redress, would have been done by the

authority; and if hereupon each person who had suffered as above could recover his compensation from the rates, local authorities would immediately have the knowledge conveyed to them, in a far more practical form than it has yet assumed in their eyes, that sanitary neglect is a mistaken parsimony.

Apart from legal technicalities, on which I do not pretend to enter, the desiderata seem to me to be these three:—first, that for any purveyor of water wilfully or neglectfully to distribute foul water, or, where filtering is required, unfiltered water, and for any local authority to make default in such duties in relation to the public health as are by statute expressly imposed on it, should be (if they be not already) indictable offences, and that the production of disease by offences as aforesaid should be also (if it be not already) indictable; secondly, that it should be the province of some named central authority to take at its discretion legal proceedings against offenders as above; and, thirdly, that where such proceedings had led to conviction, all propositions affirmed in the verdict as to the causing of disease by the convicted person or authority at the time and place in question should afterwards be held proven for the purposes of whatever civil actions for damages might then be brought by private persons on account of injury sustained through the disease. It would of course in any action for damages be matter for question and proof whether the particular suffering had resulted wholly or in part from private fault, either in resistance to a local authority or otherwise; but looking to the spirit of our present nuisance-laws, especially to section 20 of the Act of 1866, I apprehend that nuisances on private premises could not *primâ facie* be deemed matters of solely private responsibility; and in regard of a large class of such cases, it may be doubtful whether an authority could quite exonerate itself of responsibility for the nuisances, even as against the owner of the premises, unless it showed that it had taken all proceedings required of it by law in such matters, or at least that the district possessed all proper facilities for the abatement of private nuisances. As regards such indictments as are above proposed, in which generally the indictment would be only for ulterior purposes, and the proceedings therefore only nominally penal, precedent exists in the indictability of parishes or other responsible parties for omissions to repair highways and bridges.

2.—*Systematic Proceedings.*

The continuation of the systematic work which was previously in progress in the department, with the object of increasing our exact knowledge of diseases, involved during 1867 some studies which were in the highest degree interesting and important. These studies were of two different sorts, which it will be convenient here to distinguish.

Systematic Inquiries.

i. *As to the Local Distribution of Disease, and the Circumstances by which it is regulated.*

I have to recall that in my last annual report a section to which I attached particular importance related to changes produced in the

public health in certain towns where of late years improvements in drainage and water-supply had been made. The largest result of the investigation then reported on (an investigation relating to 25 towns, with an aggregate population of 600,000 inhabitants was to show very strikingly the exemption which local populations obtain from cholera, typhoid fever, and other endemic bowel affections, in proportion as the local air and soil and water are kept free from excremental pollution: a result so confirmatory of much other evidence previously collected in regard of the same ætiological question, that henceforth apparently not even the most unwilling witness can deny the relation of cause and effect in that matter. But the inquiry had also some other results, of different degrees of value. And among such results one which stood in particular relief concerned the local distribution of PULMONARY PHTHISIS.

MEDICAL OFFICER'S REPORT.

It was evident, namely, that in some of the towns which had been improved the mortality from Phthisis had notably diminished. And when detailed examination was made of the cases which gave that indication, in contrast with the different class where phthisis had not been lessened in amount, it appeared that the diminution or non-diminution of phthisis depended on whether the sanitary improvements of the place had, or had not, included any considerable drying of the soil. In cases where this condition had been fulfilled, the reduction of phthisis occured both too uniformly, and also in too great amount, to be regarded as of accidental coincidence. In a table then given, the reduction on previous phthisis-mortality, for the first 15 towns spoken of, was shown to be such as I now re-state in the adjoining table. And the fact that in some of the cases the diminished fatality of phthisis was by far the largest amendment, if not the only one, which had taken place in the local health, became extremely interesting and significant, when the circumstance was remembered that works of sewerage, by which the drying of soil is effected, must always of necessity precede, and do indeed sometimes precede by years, the accomplishment of other objects (house drainage, abolition of cesspools, and so forth) on which the cessation of various other diseases is dependent. Thus, as regards the two largest populations which were reported on—those of Bristol and Leicester, no doubt the comparative smallness of effect hitherto produced on the general and diarrhœal death-rates of those towns might (so far as it was not fallacious) be referred to the shortness of time for which finished constructions had been

Relation of Phthisis to Dampness of Soil.

The death-rates by PHTHISIS in the 15 undermentioned towns had, after improved land-drainage, fallen, *per centum* as follows:—

SALISBURY	49
ELY	47
RUGBY	43
BANBURY	41
WORTHING	36
LEICESTER	32
MACCLESFIELD	31
NEWPORT	32
CHELTENHAM	26
BRISTOL	22
DOVER	20
WARWICK	19
CROYDON	17
CARDIFF	17
MERTHYR	11

at work for the detailed dispollution of houses and their dependencies; but a reduction already of a sixth in the phthisis-mortality of Bristol, and a reduction already of a fourth in the phthisis-mortality of Leicester, were apparently connected with the fact that in both towns main sewerage on a large scale, with more or less drying of soil, had existed, in comparison, for many years. And Rugby, which, long as it had been at work, had not yet succeeded in getting rid of endemic diarrhœa and typhoid fever, showed at least this result of its main drainage works, that its phthisis-mortality had fallen 43 per cent.

The above facts, though not enough in themselves to prove as certain the very important ætiological relation which they suggested, were at least amply sufficient to show that a very promising line of inquiry had been opened. And my lords having on my representation been pleased to direct that this should be continued, Dr. Buchanan, the practised and skilful inspector who was engaged on the former general investigation, has now given me a further report of results obtained by him in a subsequent special research. That report (App. No. 5) is subjoined *in extenso.* It presents an elaborate examination of the distribution of phthisis, as compared with variations of soil, in the three south-eastern counties of England, beyond the limits of the metropolis; and it confirms, I think, beyond any possibility of question, the conclusion, previously suggested, that *dampness of soil is an important cause of phthisis to the population living upon the soil.*

This conclusion, so far as it rests on the above evidence, cannot, strictly speaking, claim to be proven for any other countries than our own; and a supposition might be advanced, though of course with little probability, that perhaps we had only succeeded in discovering an influence special to England. It is therefore with much interest that I am able to quote the result of an inquiry (which indeed was made long before our own, though it has only recently come to my knowledge) on the distribution of Phthisis in some of the United States of America. It appears that in 1862, in an address delivered at the annual meeting of the Massachusetts Medical Society, and afterwards published, Dr. Bowditch of Boston, U.S., drew attention, and not for the first time, to the remarkable inequality with which he had found phthisis to be distributed in Massachusetts, and, so far as he could ascertain, elsewhere in the States, and to the connexion of this inequality with differences of moisture of soil. He represented that "medical opinion in Massachusetts, as deduced from the written statements of resident physicians in 183 towns, tends strongly to prove, though perhaps not affording perfect proof of, the existence of a law in the development of consumption in Massachusetts, which law has for its central idea, that dampness of the soil of any township or locality is intimately connected, and probably as cause and effect, with the prevalence of consumption in that township or locality;" and he also adduced particular instances as tending to prove that even "some houses may become the foci of consumption, when others but slightly removed from them, but on a drier soil, almost

wholly escape."* It is moreover well worthy of notice that the Registrar-General of Scotland in his 7th Annual Report, adverting to Dr. Bowditch's work, has stated that, in his opinion, the mortuary statistics of phthisis in Scotland furnish evidence to the same general effect. With those corroborative statements in aid of the evidence which this department has collected, it must, I think, be deemed extremely probable that the influence of soil is universal. But at any rate as regards England, of which alone I have officially to speak, the conclusion as to the influence seems indisputable.

In submitting this conclusion as one which, in my opinion, must henceforth stand among those scientific certainties on which the practice of preventive medicine has to rest, I take the opportunity of observing (though perhaps almost superfluously) that the conclusion does not purport to be more than a contribution to the ætiology of phthisis. That vastly fatal disease, if we are to have proper knowledge of its causes, must be studied from many different points of view. On former occasions (as particularly in my 4th and 6th annual reports) I have brought into relief the industrial relations of the disease, and now I insist on its occasional endemic relations. On those previous occasions it was shown to be a disease which undergoes development in proportion as men are *unwholesomely gathered in indoor industries:* now it is shown to be a disease which also develops itself in proportion as men are *dwelling upon a humid soil.* These two conclusions, no doubt, are very great ætiological fragments; but even when taken together they do not pretend to exhaust, or nearly to exhaust, the subject of the causation of phthisis. Thus, it may suffice me in passing to note that our studies of the disease have not yet touched its immensely important *hereditary relations.* And even in the present volume I shall directly have to bring under consideration another and entirely different aspect of the disease—that, namely, in which its intimate pathological affinities have to be discussed, and the *nature of the morbid process* which establishes it. That in both those directions the acquisition of further knowledge may very greatly increase our power of preventing a disease which now causes in England probably at least an eighth part of the entire mortality, will not, I think, seem improbable to anyone who well considers the subject; but meanwhile I may point with great satisfaction to the eminently practical character of the conclusions already obtained. Phthisis, so far as it depends on unwholesome circumstances of indoor industry, has, since my former reports, been made preventable under the law;†

Causes and Preventability of Phthisis.

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* My quotations of Dr. Bowditch's work are from a second edition, which has quite recently been published in America:—"*Consumption in New England and elsewhere, or Soil-Moisture one of its chief causes;*" Boston, 1868. We here, as Dr. Buchanan states, had been entirely unable to obtain a copy of the original work; and the copy of the re-issue, which I owe to Dr. Bowditch's kindness, has reached me only since the completion of Dr. Buchanan's report.

† See Factory Acts of 1864-7, Work-places Regulation Act of 1867, and section 19 of the Sanitary Act, 1867.

and phthisis, so far as it depends on wetness of soil, may easily in great part be made similarly preventable.

Distinction must, of course, here be drawn between populous and non-populous places. An undrained state of soil in any place where population is aggregated answers to the legal intention of the word "nuisance;" and I apprehend that, even in the present state of the law, the local sewer-authority is bound to provide that such a state shall not continue through want of proper constructions for the drainage. For agricultural lands, no doubt, the case is different. It may not be practicable to require that such lands, though damp enough to cause phthisis to the comparatively few and scattered persons who reside on them, shall be artificially drained by their owners; and the interests of agriculture in this respect are not always identical with those of human salubrity. But at least the law might unequivocally condemn, so faras detrimental to health, all damming of natural drainage. And for river-conservancies it would be a function, scarcely if at all less important than that of preventing the pollution of rivers, that they should also, as far as possible, prevent or remedy all such artificial and natural obstructions of water-flow as keep tracts of inhabited land sodden with stagnant wetness.

ii. *Particular Processes of Disease investigated in scientific Detail*

Investigation of Processes of Disease.

A very important branch of the systematic work of the department is represented for 1867 by the last two papers of my subjoined appendix, Nos. 6 and 7, by Dr. Sanderson and Dr. Thudichum respectively. In my eighth report (pp. 20–1) I have stated the circumstances under which my Lords, early in 1865, determined that in future there should to a limited extent be conducted under their auspices such investigations in abstract pathology as might seem likeliest to be of ulterior effect in the more immediately practical and popular objects of this Department. The present is a time of the most extraordinary transition and progress in the sciences which are fundamental to medicine; so much so, that scarcely a month passes without raising some new pathological question which bears upon principles of action; and this Department, practically considered, would be lagging far behind the knowledge which ought to be represented in its administration, and might often be spreading mere obsolete error among persons who look to it for intelligence, if it were not itself able to submit such questions to examination, and thus and in other ways to take part in the scientific reconstruction which is in progress. The application of work of this description is, as I need hardly observe, in the first instance exclusively technical: the work addressing itself primarily to certain scientific requirements of the medical profession, and not pretending to be applicable to popular uses so immediately as the other work of the department: and, in this state of the case, it is not necessary that I should here enter, except briefly, into a discussion of the subject-matter of last year's investigations. Some short explanation, however, may be convenient.

Inoculability of Tubercle.

a. Dr. Sanderson's report relates to the process by which so-called *Tubercular Disease* is established in the animal body—such disease as, for one of its forms, is illustrated in Pulmonary Phthisis, and which, in that and other forms, is among the most fearful scourges of human life in this country. The morbid process, terribly frequent as it is, has not yet come to be well understood. Of its chemistry (which may probably hereafter prove to be the true criterion of its nature) absolutely nothing is yet known. Of the way in which its best recognized external causes become capable of engendering it in the human body, we can scarcely be said to have a conjecture. And even of its anatomy (though this of late years has been more successfully investigated) the facts are not yet nearly complete. On the other hand, its relation to some other diseases had long seemed, in a very general sense, to be tolerably sure: it had been assumed for instance—and the assumptions are represented in our commonly received classifications of disease, first, that the process must consist in "specific," as opposed to "common inflammatory," local changes; and then that the root of these changes must be something so inherent in the original nature of the sufferer, and so independent of any contagious influence, as to make tubercle the type of so-called "constitutional" diseases, in distinction from all extrinsic, and particularly from all "zymotic," diseases: but even while these assumptions were not openly contested, considerations were accumulating which caused every cautious pathologist to speak with great reserve on the subject. In this state of the case, suddenly, some two and a quarter years ago a very startling discovery was announced. Dr. Villemin, of the Val de Grâce Hospital in Paris, on the strength of a large number of experiments which he had performed on some of the lower animals, claimed to have established that tubercle is inoculable from subject to subject, and is in fact as "zymotic" as syphilis. Various observers (among whom I was one) were soon able to satisfy themselves that M. Villemin's descriptions were entirely true for the field within which he had experimented; but it was evident that no general view could properly be based on results such as his, till the answers to many other questions should have been brought within the field of study; and as the line of inquiry which he had opened would at any rate almost certainly involve immense pathological consequences, the more comprehensive research was peculiarly to be desired. My Lords, early last year, were pleased to authorize that such a research should be undertaken on a large scale in this department. One great portion of the consequent work is represented in Dr. Sanderson's present report, and other portions of it (with a view to my next annual volume) have already been committed to him for completion. The results which have hitherto been reached are not in an unqualified sense final; but even this first stage of the inquiry, besides leading as it does to ulterior questions of the utmost interest, has already given us definite and important knowledge.

The conclusions to which hitherto we have come may be stated as follows. First, M. Villemin's fact is established as unquestionable:

certain of the lower animals, if inoculated from the human subject with the morbid products which are called "tubercular," will in consequence develop, more or less extensively throughout their bodies, a disease, which, so far as present criteria can decide, is identical or nearly identical with the so-called "tubercular" disease of man: and from this fact, taken with previous knowledge as to the mode in which "tubercle" in man tends to spread infectively from its original site to secondary and tertiary sites in the affected body, it would at first seem that human "tubercle" must be a specific zymotic disease. Against this, however, the correction has to be applied, that, in the rodent animals on which hitherto an immense majority of the inoculative experiments have been performed, a disease, which, if it were in the human subject, we should unhesitatingly call "tubercle," may certainly and (it seems) very easily arise in continuation of "common inflammatory" phenomena; that not only the "tubercular" inoculation from man, but other morbid inoculations, and even "common" local lesions, may be followed by diffuse tuberculisation of the rodent's body; that, for instance, a slight open wound, such as that of a seton run beneath the skin, is not, as in man, an affair of simple irritation which ceases when the irritant is withdrawn, but is capable of being the first step in a series of changes which gradually infect the creature's whole body with imitations of the human "tubercular diathesis," and thus at last create such "tubercular" disorganizations as necessarily destroy life.

Here, for the present, we stop, and it would be idle to conjecture what further knowledge may hereafter be gained in this very instructive line of inquiry. I may venture, however, to point out that some of the present observations, in converse as it were to their first teaching, prompt a curious second reflexion. They suggest, namely, a speculation with regard to human "tubercle," such as may indeed extend to many human diseases which are called specific and zymotic, whether perhaps our pathological terms "common" and "specific" may not, more than has yet been supposed, be found variable with the particular animal spoken of as affected, rather than attaching fixedly to the given diseases; whether, namely, the "common inflammatory" affections of some animals may not be the "specific" affections of others; whether, for instance, some "common" traumatic affection of this brute or that may not correspond in essential chemistry to this or that "specific" zymosis of man, and even in some cases be the source whence the latter was first derived. Of course no speculation of this sort can be conclusively argued till our present imperfect scientific definitions of morbid processes shall have been very greatly improved.

Chemical Researches.

b. Dr. Thudichum's report, even in some respects more than Dr. Sanderson's, represents only part of an unfinished work of the department: but here the projected work is so large and heterogeneous that of necessity its separate sections must often be regarded as wholes. The scope of the entire work is an

endeavour which my Lords are making in this department to contribute towards the establishment of precise knowledge in those chemical aspects of pathology where at present there is almost utter darkness. It is only among persons who are fairly conversant with the present difficulties of the medical sciences that the full obstructiveness of that defect can be measured. It means, alas, that very large parts of practical medicine, both preventive and curative, are even yet in a state of grievous imperfection. Both within and without the profession, certain general words which have become current are apt to convey erroneous impressions on that subject. With our various infectious "fevers," for instance: —we state that they have, as their common and probably essential character, an extraordinary development of contagious chemical activity (or, as we call it, "fermentation" or "zymosis") in the affected body; but behind these general words there is so little exact knowledge, that we have not the remotest conception wherein the "chemical activity" of smallpox differs from that of scarlatina or of typhus, or what is the chemical difference between their respective fevers and the fever of a broken leg or skull. Similarly with our so-called "dyscrasies": — we are ready to tabulate together under that old Greek word a large number of diseases of which we think we know that they represent habitual indolence, or other chronic misbehaviour, in the chemical working of the body or of certain organs—such habits of body as the gouty, the scrofulous, the rheumatic: but not of one of these dyscrasies, not even of the most studied of the number, are we yet able to give any description which a chemist would recognize as intelligible. And this, be it observed, is in regard of diseases which by common consent are either primarily, or in a high secondary sense, chemical. Of course a third group might be cited of other diseases, which also (like the above) present very prominent chemical phenomena, but which hitherto are so imperfectly known in this point of view that we hesitate whether to call them dyscrasies or not: such diseases as cancer, rickets. Here in short is a large number of our most important diseases, for which hitherto we have not even approximately got proper pathological definitions. And the evil of this is not only that in our purely scientific discussions we are again and again brought to a standstill by the embarrassment of undefined terms;* but also the defect which I describe lies at the very root of what is now least satisfactory in our practice. What we want in respect of our morbid processes, so far as they concern the chemistry of the body, is to be able to define them in precise chemical language: to be able, for instance, as regards any disease which is rightly considered

* For instance, some two years ago, when the cattle-plague began to be much talked about here, public discussion arose whether the disease was of such nature that it ought to be called bovine smallpox; but this discussion was (I may venture to affirm) simply futile, as no one could define "smallpox" in any sense which would supply a reasonable standard for the comparison. And the same sort of thing is illustrated to some extent in what I have written in the preceding section as to the communicability of "tubercle." For, what is tubercle?

zymotic, to say that the bodily materials which it specifically affects are such and such, and that in the disease these materials pass through such and such stages of transformation, ending in such and such results: and to be able to express all this in as exact chemical terms as we apply to vinous or butyric fermentation. Failing this, we have no final pathology of such cases as are in question; nor is it likely that we should have for them, except by accident, any radical treatment or prevention. No doubt there may be lucky successes, as where we inherit specific antidotes or half-antidotes, more or less uncertain, for gout, or syphilis, or ague; and there are the many far different successes, where the skilful practitioner with treatment which is confessedly but provisional and palliative (though not on that account the less scientific) avails himself to the utmost of present symptomatological knowledge, and watchfully resists disease in the detail of each special influence by which it proximately tends to shorten life. But the total of these various successes leaves still much unsuccess to be deplored; and probably those who are most efficient in administering the present resources of medicine would be of all persons the most conscious how limited in some directions, and specially in such as I am now considering, are the resources which are yet at their command. And evidently for future progress, the possibilities of medicine are but two: on the one hand we have the chance, such as it is, that from time to time new specific antidotes may accidentally be discovered; on the other hand, there is the power of deliberate scientific discovery and application. The latter, in regard of such chemical diseases as are here under notice, must presumably, in some or all of the most important stages of its development, be a question of purely chemical work; and it would, I think, be unwise to assume in respect of any such chemical case, that the ends of preventive and curative medicine can be reached till our practical proceedings shall have got to be demonstrably based on the very chemical formula of the morbid process.

There is here of course no intention to depreciate in even the smallest degree the services which other kinds of observation and experiment as to the forms and forces of health and disease may render, and have rendered, to medicine. Every step in the physiological sciences, every better knowledge of the organs of the living body, and of their material and functional fluctuations under whatever influences, is of actual or potential gain to us; and such knowledge, even where it sometimes tends but little to the final interpretation of disease, constantly gives more and more success to the provisional practice which it enlightens. As regards the anatomical studies of late times, with the very advanced utilisation of the microscope, and the otherwise greatly improved means of minute structural investigation, I need hardly say that, by them, during the last thirty years, great parts of the science of disease have been completely transfigured, and that even now from year to year this mode of inquiry continues to give most valuable results. How much importance is attached to it in this department is indeed illustrated in the present volume by the minuteness of

anatomical research with which Dr. Sanderson's report is written. But one of the best lessons which any science can teach us is enabling us to see what are the necessary limits of its own teaching-power; and thus by help of the microscope we have come to learn, in respect of a vast number of the most important problems of pathology, that what it can teach is only generic, while what we want to know is special, that diseases practically most dissimilar may be indistinguishable in ultimate anatomy, that our few simple types of structural change are but vague and most imperfect symbols of the innumerable chemical changes which they embody. Nor, as regards the zymotic diseases, do I undervalue the great scientific interest of such investigations as I last year quoted from Prof. Hallier in respect of cholera, and might now quote from him in respect of several other such diseases, as tending, in his belief, to establish that micro-fungi of various sorts constitute zymotic contagia; but, however great may be the future development of such investigations as those, and however unquestionable their results, the field in which such knowledge might prove applicable is one where in most instances the interest of the microscopic ferment would be practically as inseparable from the chemical study of the disease, as the interest of the yeast-plant is inseparable from the study of the decompositions amid which it lives.

The above, in substance, are views which I have for many years entertained and expressed as to the very great need of chemical research in aid of such practical objects as those with which this department is charged: but till very recently such researches could not have had much promise of success: and it was only three years ago that I felt justified in asking my Lords to allow me special assistance for an attempt to lessen the defects of which I complain.

Of the work which since then has been done for the Department by Dr. Thudichum, part was represented in my last year's volume by a report on the chemistry of cholera, and another considerable part is now represented in my subjoined Appendix, No. 7. The medical reader will see, without surprise, that a large proportion of the present work is of a kind which may almost be called preliminary; partly that it deals with those sections of physiological chemistry with which our great patho-chemical problems are most nearly related, and in which, essentially for our purpose, very exact standards of healthy chemical process have to be ascertained; and partly that much study is given to artificial and post-mortem processes which in some degree resemble processes of disease. The more direct researches have brought into strong light (as may particularly be seen in section 3 of the Report) the necessity which caused that course to be taken. The present researches, besides investigations of particular morbid phenomena, have chiefly related to the decompositions of albuminous substances, to the colored corpuscles of the blood, and to the coloured ingredients of bile and urine. It has been found convenient to

prefix to the account of these researches a compendious introductory view of the present state of the case to which the researches apply; or (as the title of the section runs) a "sketch of chemical physiology, and of its points of contact with pathology." Further, the spectroscope has proved so essential an instrument of investigation as to require particular notice in the report; and, therefore, the information given as to the spectroscopy of the blood is preceded by some general information as to the construction and uses of the instrument. Also the report has a supplementary section on alcohol and its relations to the human body; particularly in settlement of the much-debated medical question whether alcoholic drinks contribute to nourish the body into which they are taken.

John Simon.

APPENDIX.

No. 1.—STATISTICS OF THE NATIONAL VACCINE ESTABLISHMENT.

1. STAFF of the ESTABLISHMENT at end of 1867.

N.B.—The Stations named in *italics* are Educational Vaccinating Stations, authorized by the Lords of the Privy Council, for the purposes of their Lordships' Order of December 1, 1859.

—	Members of the National Vaccine Establishment supplying Lymph for the Public Service.	Vaccinating Stations.	Days and Hours of Attendance.
Vaccinators salaried from the Parliamentary Grant.	Mr. John Newton Tomkins, Inspector.	Fitzroy Street.	Mon., Tues., Wed., Thur., Fri., Sat.; 10—11.
	Mr. James Furness Marson.	*Surrey Chapel, Blackfriars Road.*	Tuesday, Thursday; 1—2.
	Mr. George Lewis Cooper.	Battle Bridge.	Tuesday; 12—1.
	Dr. Richard Sharpe -	Bermondsey.	Tuesday; 10—11
	Mr. Robert Wade -	Dean Street, Soho.	Monday; 9—11.
	Mr. Arthur Bernard Macann.	King Street, Portman Square.	Monday; 10—11.
	Mr. Wm. Jones Lewis.	Spital Square, *Wellclose Square.*	Monday; 10—11. Tuesday; 9—11.
	Mr. W. E. Grindley Pearse.	*Tottenham Court Chapel.*	Monday, Wednesday; 1—2.
Parochial and other Vaccinators not salaried from the Parliamentary Grant, but furnishing Lymph at a fixed rate of payment.	Mr. Ellis Southern Guest.	*Manchester.*	Monday; 2—4.
	Mr. John Garner -	*Birmingham.*	Monday; 10—12.
	Mr. William Yeoman Sheppard.	*Bristol.*	Tuesday; 11—12.
	Mr. Arthur Browne Steele - -	*Liverpool.*	Monday; 9. Friday; 2.
	Mr. John Henry Wilson - -		
	Mr. John Fenton -		
	Dr. Edward Lowe Webb.	*Pimlico.*	Monday; 10—12.
	Mr. George Cuthbert Gilchrist.	*Newcastle-on-Tyne.*	Tuesday; 2—3.
	Mr. William E. Grindley Pearse -	*Westminster.*	Monday; 9—11.
	Mr. James George Gerrans.	*Marylebone.*	Monday; 10—11.
	Mr. Frederick Holmes	*Leeds.*	Tuesday; 3¼.
	Dr. Edward Lynes -	Coventry.	Monday; 12—2.
	Mr. Joseph Teale -	Salford.	Thursday; 2¼.
	Dr. James Dunlop -	*Glasgow.*	Monday; 12—1.

Statistics of the National Vaccine Establishment—*continued.*

2. SOURCES and AMOUNT of LYMPH SUPPLY in 1867.

N.B.—The Stations named in *italics* are Educational Vaccinating Stations, authorized by the Lords of the Privy Council, for the Purposes of their Lordships' Order of December 1, 1859.

—	Vaccinating Stations.	No. of Vaccinations performed at the Stations respectively.		No. of charges of Lymph supplied from the Stations respectively.	Remarks.
		Primy	Revacs		
Vaccinators salaried from the Parliamentary Grant.	1. Fitzroy Street	478	—	5,200	
	2. *Surrey Chapel*	968	52	14,100	
	3. Battle Bridge	474	—	5,294	
	4. Bermondsey	534	61	7,696	
	5. Dean Street, Soho	421	24	10,080	
	6. King Street, Portman Square	257	12	4,556	
	7. Spital Square	276	—	10,992	
	8. *Tottenham Court Chapel*	1,506	58	13,756	
	9. *Wellclose Square*	244	—	9,678	
Total	9 Stations	5,158	207	81,272	
Parochial and other Vaccinators not salaried from the Parliamentary Grant, but furnishing Lymph at a fixed rate of payment.	1. *Manchester*	1,334	7	17,640	
	2. *Birmingham*	1,157	54	5,583	
	3. *Bristol*	252	—	1,600	
	4. *Liverpool*	919	7	16,287	
	5. *Pimlico*	870	106	34,975	
	6. *Newcastle-on-Tyne*	383	26	8,265	
	7. *Westminster*	784	18	15,602	
	8. *Marylebone*	1,073	153	10,724	
	9. *Leeds*	464	6	8,257	
	10. Coventry	464	—	1,660	
	11. Salford	755	—	7,212	
	12. *Glasgow*	714	—	7,560	
Total	12 Stations	9,169	377	135,365	
General Total	21 Stations	14,327	584	216,637	

Statistics of the National Vaccine Establishment—*continued.*

3. SUMMARY for the Years 1856–1867.

Year.	Total Vaccinations performed at the Stations which supply Lymph.	Re-vaccinations included in preceding Column.	Number of Charges of Lymph supplied.
1856 - -	7,039	?	210,942
1857 - -	6,327	?	213,207
1858 - -	6,445	?	234,150
1859 - -	9,030	?	237,801
1860 - -	13,849	?	228,347
1861 - -	12,009	?	225,000
1862 - -	13,149	?	211,475
1863 - -	20,600	?	239,432
1864 - -	13,727	?	203,250
1865 - -	14,648	515	219,832
1866 - -	14,319	372	207,014
1867 - -	14,911	584	216,637

No. 2.—EXTRACTS from REPORT by Dr. R. THORNE THORNE on EPIDEMIC TYPHOID FEVER at WINTERTON.

* * * * *

Winterton is a small market town, situated on a gentle slope, in the northern part of the county of Lincoln, about two miles south of the Humber. It consists mainly of one street, called the High Street, running directly from east to west, but at the western extremity houses are also collected around an open space originally occupied by a pond, and round two sides of the churchyard. The town, which is on high ground, is situated on a stratum of oolitic limestone, which is very porous, and easily admits of the percolation of fluids. Above this substratum lies a clay marly soil.

In 1861 the population was 1,780, and since that date it has, for two reasons, not increased beyond about 1,800. The first of these is the establishment of ironworks at a neighbouring village, where many of the inhabitants now find employment, and where they have, in consequence, settled. The second and more important reason is, that until the Union Chargeability Act was passed, the nobility in the adjoining parishes refused to allow of any cottage property or of paupers on their estates, and Winterton being a freehold town, the labourers who worked the land for a circuit of nearly four miles around, all took up their abode there. Recently, however, the paupers being maintained out of the general union rate, instead of the parish rates, the landowners have commenced to build cottages on their own property, where their labourers now reside.

The town is under the government of a local board, the only other officials being the clerk to the board, and a labouring man who holds the appointments of town surveyor and inspector of nuisances. Its situation on a slope gives great natural advantages to Winterton as regards sewage, and within the last few years a very effectual main drainage has been laid through the town. Into this drain a running stream has been diverted, and thus a continual flow of water is kept up nearly throughout its whole length. Two outfalls carry the drainage into a brook running parallel with, and outside the town; this discharges itself into an artificial piece of water called Sir Rowland's Drain, which in its turn runs directly northwards, and joins the Ancholme river, just before this stream empties itself into the Humber. All the openings from the street gutters into the drain are well constructed and properly trapped, and with the exception of one of the outfalls which have just been mentioned, and to which reference will again be made,* the whole system works efficiently. The town consists almost entirely of cottages, which are, with few exceptions, well built, of brick or of limestone. Absolute poverty is but little known there, for though about nine-tenths of the population consist of the labouring classes, yet these, when in health, almost all earn good wages; intemperance, also, is rare, so that neither of these causes can be said to be at work in predisposing the inhabitants to disease. Ague was up to 30 years ago very prevalent in the district, but since the neighbourhood has been properly drained no cases have occurred.

The mortality of the town for the last 10 years has been as follows:—

For the year	1857 - - -	34	deaths
„	1858 - - -	47	„
„	1859 - - -	42	„
„	1860 - - -	33	„
„	1861 - - -	37	„
„	1862 - - -	32	„
„	1863 - - -	31	„

* Vide page 32.

For the year	1864 - - -	59 deaths	
„	1865 - - -	51	„
„	1866 - - -	44	„

The increase in 1864 was mainly due, I am informed, by the union medical officer, Mr. Bennett, to an epidemic of scarlet fever, and since then to the prevalence of the fever which has been the cause of this inquiry.

Winterton is at present suffering from a widely spread epidemic of typhoid fever. This disease, according to Mr. Bennett, has never been entirely absent from the town for nearly seven years, but during the last two or three years only has it affected so large a number of the population as to give rise to public anxiety. The epidemic is now *principally* confined to the east end of the town, where it has attacked the poorest class of the inhabitants, but during the past year almost all the cases occurred at the west end, in the houses adjoining the churchyard. These houses are 35 in number, and Mr. Bennett's books show that from June 1865 to June 1866, out of 145 persons residing in them 100 suffered from fever, of whom 17 died. The upper classes and the tradesmen have not been exempt from the fever, but at the time of my visit none but the labouring classes were suffering from it.

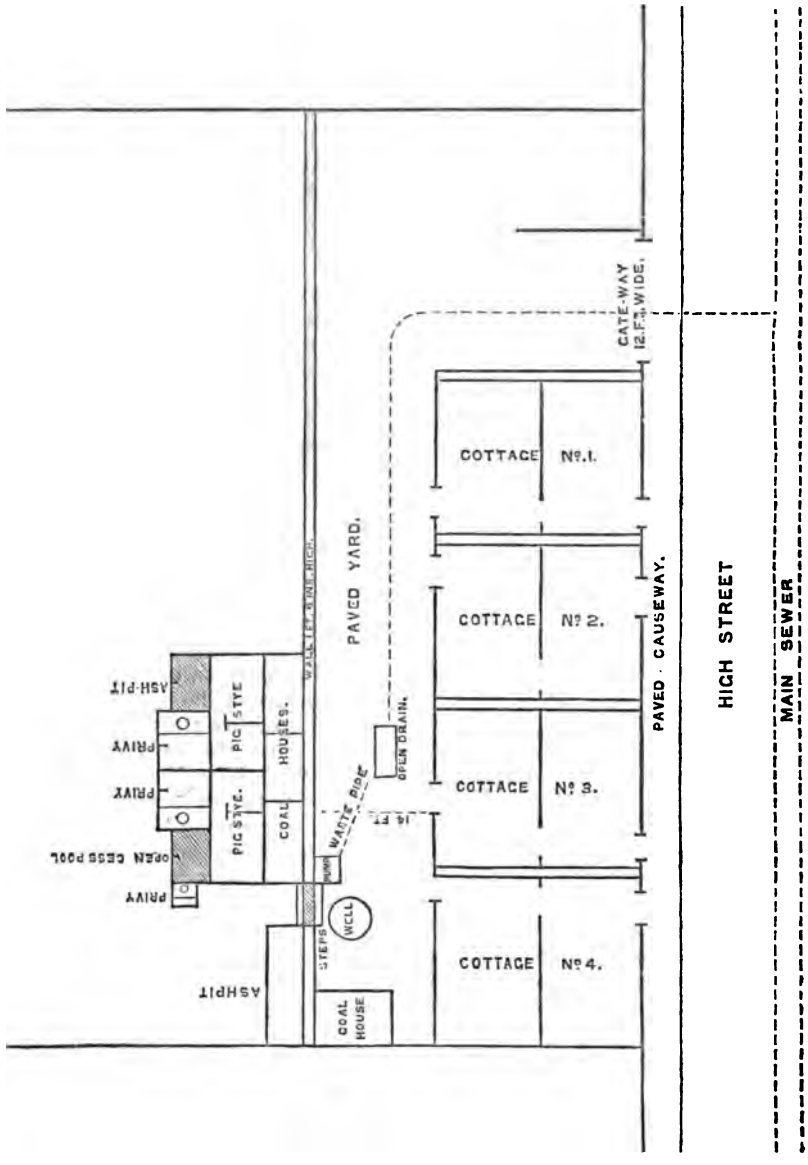
From Mr. Bennett's position as union medical officer, almost all these patients are under his care, and by his permission I visited with him all those who were now under treatment. The number I thus saw was 49, all of whom exhibited the various symptoms of typhoid fever, including the rash and the bowel affection, with the exception of a few whose cases were of too recent a date for the eruption to have exhibited itself, and a few more who were progressing towards convalescence, but who had evidently suffered from some acute febrile disease. In addition to these cases there were six under Mr. Sadler's treatment, making a total of 55 cases. Notwithstanding this large number, the mortality has been small, six cases only having terminated fatally since the 1st of January this year. This is to be accounted for by the fact that at the present time the disease is in by far the majority of instances of a mild type; indeed I saw several patients sitting up, who had well-marked rose spots about them, and were suffering from diarrhœa at the time of my visit.

The epidemic prevalence of fever in Winterton is undoubtedly to be ascribed to the disgraceful state of the privies, cesspools, ashpits, and wells. With the exception of about six houses, where waterclosets have been constructed, all the cottages are provided with privies, which are generally built of brick, and have an aperture at the side or back, through which they can be cleaned out. This aperture I found open in almost all instances, and the result of this is that the contents of at least half the privies in the town run out into the gardens, soak into the earth, and penetrate in many instances into the wells, besides producing the most offensive odour. In addition to this many of the tenants either throw their refuse and slops, including urine, into the yards outside their doors, or else they improvise a receptacle by digging in the ground close to the aperture in the privy wall. The fæcal matter pours into it, and they thus add to their previous list of nuisances that of an open cesspool. In some instances ashpits have been built, but these are uncovered, and since urine and the bowel discharges of the typhoid patients are thrown into them, in addition to other refuse, they are but little better than open privies. All these sources of fæcal fermentation are situated as a rule close to the houses, and in some instances within a few feet of the back doors, and just under the windows. The wells are also in their immediate neighbourhood, and many of the inhabitants informed me that their water was so bad that they had been compelled to discontinue drinking

it. In one instance I found the space between two pigstyes entirely occupied by a well 3 feet in diameter. Fever is present in the house to which this well is attached, but since the occupants do not use it, the necessarily contaminated condition of the water cannot be considered to bear upon the disease. Given, the existence of typhoid fever in a town, it is hardly possible to conceive of conditions more favorable for its spread than those existing in Winterton.

The record of a few cases differing in no essential points from all those I visited, will exhibit something of the evidence on which this statement is based.

A group of four cottages, the property of Mr. Dale of Appelby stand in the High Street; their back doors all opening into one common yard



14 feet wide (*vide* diag.) In front of the third house and within 5 feet of the windows is an open untrapped drain, which communicates with the main sewer, but owing to this communication being defective a large quantity of stinking fluid which partly consists of urine, has accumulated there. Within 8 feet of this is the pump, from which a waste pipe runs into the drain ; but when the drain does not properly empty itself, that is to say, when it is in the condition in which I found it, the fluid regurgitates up towards the pump. The well which supplies all these four cottages with water lies 2 feet to the west of the pump, at the foot of two steps leading into the gardens behind the cottages ; these gardens being raised above the yard, and sloping towards it. Close by these steps and overhanging the well, is an open ashpit, on which the bowel discharges of typhoid patients are thrown, in addition to filth and almost every description of decomposing matter, which it is possible to conceive. A few feet higher up the garden, and within 6 or 7 feet of the well are two pigstyes. Immediately behind these, and raised slightly above them, are three privies, and one cesspool; two of the former are filled with night soil nearly up to the seats, the remaining one is less full because it empties itself into the open cesspool. The pestilential odour in the neighbourhood of this group of nuisances it would be almost impossible to describe ; suffice it to say, that on pointing them out to the inspector of nuisances, that official, as on several other occasions, politely begged to be excused from approaching them any nearer. In short we have within a circuit of about 14 feet round this well one open drain, one open ashpit, two pigstyes, three privies, and one open cesspool, all of which with the exception of the drain, are raised to a height varying from 1 foot 6 to 3 feet above it, and situated on a loose porous soil.

As a result of this I found that in cottage No. 1, where three persons live, two have had fever, of whom I saw one, viz. Joseph Hewson, a labourer, who was evidently recovering from some acute febrile affection. No. 2 was empty, but I ascertained that up to eight weeks ago, four persons resided there. The neighbours told me that "they were always ill," and Mr. Bennet stated that one of them had died of fever. No. 3. Here seven persons live, all of whom have had fever. In this house I found in a small room 12 feet × 8 feet and 7 feet high, Henry Driffell, bricklayer, ætat 32, lying in a semi-comatose condition, on a mattress saturated with urine and fœcal matter, to such an extent that the ammoniacal and fœcal emanations were absolutely pungent, and I was compelled to go to the window which I found closed, and open it, in order to breathe some fresh air. Covering the patient were a blanket and a sheet, also saturated with his discharges. The nurse, who had been provided by the parish, was so exhausted from continually watching him day and night, that she was no longer able to move him, and if she had been, she stated that it would be useless, as she could obtain for him no change of linen. . . . . In another room lay this man's wife, who was also attended by the same nurse. In No. 4 four persons live. I examined them, and found them all free from disease. They informed me that they had never been ill.

On continuing my inquiry I ascertained that the inmates of cottages Nos. 1, 2, and 3, where the epidemic has been so rife, all of them drink the water from the well just described ; those living in No. 4 and who have always enjoyed good health, not liking the taste of it, have drawn their water from a neighbour's well.

Nothing could point much more conclusively to the contaminated state of this water, and on examining it I found it to be of a light brown

colour, and disagreeable taste, and to yield a considerable deposit after standing for a few hours. Under the microscope it exhibits a large quantity of organic matter, both animal and vegetable, as well as infusoria and animals of a low type (*vide* diag.)

As a second example I will draw attention to a house situated also in the High Street, the property of Mr. Dent, M.P., and occupied by William Backhouse and his family, in all four in number. I there saw Alice Backhouse ætat. 4, who had been attended by Mr. Bennett for "fever," which from the symptoms enumerated including diarrhœa and hœmorrhage from the bowels, was evidently of the typhoid type. The patient had recovered from the acute stage, but was frightfully emaciated, had abscesses over the tibiæ, and several bedsores, as the remote effects of the disease. In the house itself I found the chamber utensils containing fæces and urine although my visit was made at about midday. Thirteen feet from the door is an open ashpit on which some of the fæcal discharges of the patient named had been thrown, and where they still lay uncovered. By the side of this is an open drain. At a distance of about 30 feet from the house is the opening from the main drainage into the second outfall to which I have referred above (*vide* page 28). Close by stands the privy used by Backhouse and his family. This privy is built on the edge of the outfall, and by an aperture in one of its walls it empties itself into it. The outfall is merely an open ditch, the contents of which, contaminated as they must be by the typhoid discharges from the privy, I found spread out on the tenant's garden, this proceeding having been ordered by the town authorities for the purpose of cleaning it out. The stench just around this outfall, privy, and ashpit was worse than anything I found in the whole town. The water on these premises was never used for drinking purposes on account of its bad taste, and therefore it cannot have had any influence in causing the disease. I examined the premises from which they borrowed water, but was unable to detect any source of contamination.

One other set of cottages, two in number belonging to a gentleman named Fowler, will furnish me with my last example, and I refer to these particularly because they afford the only instances of overcrowding with which I met.

Both these cottages are again situated in the High Street, and the first is occupied by a family of nine persons named Altoft. Among them five cases of fever have occurred, one of which has proved fatal. On examining the interior of the house I found that nine persons slept in one room, of which the window was habitually closed, and the fireplace blocked up with bricks and cement. I took a measurement of the room and thus ascertained that each individual had less than 160 cubic feet of air. The privy outside was full to within 6 inches of the seat, stale urine covered the floor, and the soil was exuding through the brickwork at the back and escaping into the garden. There being no ashpit either to this cottage or the next one, all the slops, including urine, are thrown into a yard behind, and within a few feet of the doors

I found strewed indiscriminately, ashes, straw, fish, and vegetables undergoing decomposition. The next cottage is inhabited by six persons named Hill, five of whom have suffered from typhoid fever; one of these I saw with all the characteristic symptoms. He lay in a room 8 feet × 6 feet; this he shared with two others, each person only having 96 cubic feet of air. In addition to this, the room which is on a level with the street has a damp brick floor, and no window or fireplace, the former having been blown away by a gale some months ago, and not being replaced the tenant has been compelled to board the opening up. Thus neither light nor air can penetrate the room. The privy adjoining this cottage is so full that its contents rise literally above the seat, and I was informed that it had been in this state for six months; the inmates are thus compelled to resort to the one belonging to Altoft's cottage, which on this account is used by 15 persons.

The cases enumerated are fair examples of what I found throughout the whole town. In some instances I endeavoured to ascertain whether the fever could have had a spontaneous origin, but the inhabitants all seem to be on such terms of intimacy with each other that they continually frequent the infected houses, there assist in attending to the sick, and thus come into contact with the bowel discharges, or else they drink the contaminated water. My inquiries therefore failed to elicit any information on this subject, and owing to the fever having now existed in the town to a greater or less extent for nearly seven years, I was unable to ascertain the manner in which it first originated.

I paid a visit to all the slaughterhouses, and with the exception of one, they were clean. The one referred to belongs to a butcher named Bulliment, and here I found in an open yard, a mass of putrid offal and entrails; I was informed that they are never removed until the butcher "can stand the smell no longer."

From the statements I have made, it is evident that the work which an inspector of nuisances is generally supposed to do, is in Winterton entirely neglected.

Among those groups of cottages to which my instructions especially referred, the only two where I found anything worthy of notice, were those belonging to Mrs. Porkuss and Mr. Bennett. In one cottage on the former property, the privy, into which the bowel discharges of a patient who had died of typhoid fever had been thrown, was situated within 3 feet of the house, the door being exactly opposite the house door and close to a window. Like all other privies, it contained soil to within a few inches of the seat, and emitted a most offensive effluvium. Mr. Bennett's cottages were all clean, and I found no illness there.

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No. 3.
On an Outbreak of Typhoid Fever at Guildford, by Dr. Buchanan.

No. 3.—Dr. Buchanan's Report on an Outbreak of Typhoid Fever at Guildford.

§ I. Inquiry into the circumstances of the recent outbreak of typhoid fever at Guildford was made on September 25–27th, and information since received brings the facts down to October 1. An account of the fever must be prefaced by a short statement of some matters relating to the general sanitary condition of the town.

Guildford is placed on the side of a hill of Chalk, where it is cut through by the valley of the Wey. The northern, and more level, part of the town, which extends into the parish of Stoke, are on a bed of Lower London Tertiaries overlying the Chalk. This bed is of somewhat marly sand, and has a maximum thickness of 15–20 feet. But it is with the larger portion of the town, built immediately on Chalk, that this report is most concerned.

The Chalk furnishes a perfect natural drainage for the town. Cesspools sunk into it keep themselves dry, and are commonly so inoffensive that they are not emptied for many years together. The water-line in the Chalk is of course much below the surface of the higher part of the town; at the lower parts water is easily reached at a level a little above that of the river surface; into the river considerable springs from the Chalk constantly pour. The water-level under the town undergoes no appreciable fluctuations, either from changes of season or of artificial influences.

There is no recognized system of closet drainage in Guildford, but cesspools into the Chalk are almost universal. Shallow sewers receive surface water from most of the streets and slops from the houses, and into some of these sewers more or less night soil—chiefly the liquid portions of it—is discharged. This is without the consent of the authorities, as the sewers were never constructed for such a purpose.

The water supply of Guildford is derived partly from the public waterworks, which are fed by two wells sunk some 20 feet into the Chalk at the lowest part of the town; an old well from which water is raised by the power of an adjacent watermill; and a new well from which, from April to July inclusive in the present year, water was distributed to the higher parts of the town by engine power. But of the 1675 houses (1867) of Guildford, only 928 are supplied from these sources, the remaining 747 obtaining their water from private wells and some few from the river.

The population of Guildford in 1861 was 8,032 in 1,514 houses. The population is now estimated at 9,000, and the number of houses is 1,675. There is some subletting of houses, but very little serious crowding in the town. The occupations of the people are various, agricultural and manufacturing, but offer nothing to note in the present report.

§ II. Typhoid fever not unfrequently prevails in Guildford and the neighbouring villages. The district of Guildford stands second highest amongst extra-metropolitan registration districts of Surrey for its deathrate from fevers, but the best local opinion ascribes this circumstance to the frequency of fever in other parts of the district rather than in Guildford itself. In the present summer, cases of

typhoid had occurred from time to time in various neighbouring villages, and some few in the town before the time of the outbreak under question. During the first four weeks of August about 10 cases of fever appear to have occurred in the town, six of them being reported by one practitioner.

In the last three days of August cases of typhoid fever came under treatment in Spital Street and Pannell's Terrace, high lying and usually very healthy parts of the town. In the first two days of September a few others came under observation, and on September 3rd and 4th a surprisingly large number of people sent for medical assistance and were found to be suffering under the same fever. In the first 10 days of the month a total of some 150 cases had come under treatment, and this number had increased to 264 by the end of September.* A singular circumstance soon forced itself on attention in connexion with this outbreak. Whereas the few cases that had previously happened in Guildford had been scattered through the poorer low lying parts of the town, this sudden outbreak was restricted with almost absolute precision to the high levels; well-to-do people were affected as much as the poor; streets in various quarters of the town were affected; the best kept houses were invaded as much as dirty ones. Except the coincidence with high level, there was nothing approaching uniformity in the distribution of the epidemic.†

The outburst reached its greatest intensity before the middle of September, and thenceforth declined pretty rapidly. Meanwhile a very few cases were occurring at other parts of the town. At the time of inquiry only a few new patients were coming under observation, and these were increasing in number in parts of the town that had not been affected by the first explosion.

Looking carefully for any condition which might coincide in distribution with the fever, it was soon seen that drainage could have played no direct part in the result, inasmuch as there is no system of sewers in the town, and the parts affected were those whose natural drainage is the best. Other suggestions having been put aside as not meeting the broad facts of the case, only one condition was to be discovered generally coincident in distribution with the outbreak, and that was the *high service of the town water supply.*

More particular inquiry was then made as to the source from which each affected house procured its drinking water, and it turns out that all the houses *first* attacked at the beginning of September were supplied with water from the high service. A few exceptions to the absoluteness of this rule were in school children and others who, living in houses not supplied by high service water, spent the hours of the day in houses that got their supply from the high service. In the latter part of September new attacks had been less exclusively distributed to such houses.

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* The mortality of the fever cannot yet be stated. Only three cases had been fatal at the end of September. Some other persons who were then ill have died while this report has been in preparation. Evidently the deathrate will turn out to be very low, a fact of interest in connexion with the transitory operation of the apparent cause of the fever.

† The parts affected by the outbreak are all on Chalk. Sporadic fever has shown no preference for the Chalk, rather for the more level and lower lying Tertiary parts of the town.

Of the total number of 264 cases of fever that have occurred in Guildford in August and September, 177 have been in the 330 houses that derive their water from the high service mains; only 30 have occurred in the 598 houses that are on the low service, and 57 cases in the 747 houses that take no water from the public works. Even these figures show an incidence of the fever on the high service houses ten times as great as on the low service; but this does not express the true limitation of the outbreak. If the few sporadic cases occurring before August 28th, and those that did not occur until the end of September, when the disease was getting more diffused, be excluded, there remain not more than two or three dozen cases (out of the 150 that occurred between August 28 and September 10) in houses that did not get high service water. And if deduction be made of the school children above mentioned there remain less than a dozen persons attacked in this fortnight who had not had daily and hourly access to the water of the high service. (*See postcript.*) The experience of all the medical men has been combined in this conclusion; but the practice of the Surrey County Hospital may be quoted in illustration. Careful inquiry by the resident medical officer showed that of 39 cases coming under treatment there between September 3 and October 1 (he had seen no fever for weeks before) 26 lived in houses supplied by high service water, 4 in houses supplied by low service water, and 9 in houses that got water from their own wells. But of these last 13, 10 were children who in August went to schools supplied by the high service water. Two of the other three cases did not come under treatment till October 1, and the third was on September 20th at a village three miles off.*

The coincidence of the fever outbreak with the area of high service water supply being thus strongly marked, and the cause of the disease having evidently come into operation about the middle of August, it was at first sight perplexing to be told that since the beginning of August identically the same water had been delivered to both the high and the low service districts of the town. The engine which pumped water from the new well to the high service mains and to the high service

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* Mr. Taylor had had 60 cases of typhoid, little or none before September 3rd. His earlier cases were all in houses supplied by high service water. In all 43 of the cases had been in houses so supplied; 7 had been in houses on the low service, and these included 4 children who went to school in the high service district; 8 were in houses with wells, and of these persons 5 went to school or where employed where high service water was in use; two cases were beyond the town in persons who had worked in houses similarly supplied. Very similar distribution had occurred in the practice of Dr. Stedman, Dr. Morton, Mr. Eager, Mr. Butler, and Mr. Schollick, and the outbreak in the practice of each of these gentlemen had occurred about the same day, and was at first wholly in houses supplied by high service water, scarcely any cases of the fever having been previously under their care. The most numerous cases of scattered fever had been in the practice of Messrs. Sells and Wilson, probably from the circumstance of their holding a poor-law appointment in an unwholesome district. Their experience, though not identical in form with the rest, is wholly confirmatory of the above conclusions. In the first 28 days of August they had no case of fever in houses supplied by the high service, one in a house supplied by the low service, three in houses of the town supplied from wells, and five cases in the the surrounding country. In the 17 days, August 28th to September 14th, the number of attacks among their patients whose houses are on the high service was 22, in houses on the low service three; in houses with wells, nine; and in country parts six. In the 16 days September 15th to September 30th the new attacks in high service houses had diminished to 14, but those in houses supplied by low service had risen to six, those in houses with wells to 10, and those in the country districts to eight.

reservoir had broken down on August 1st, and from that date no water had been pumped from the new well, but the high service mains had been charged by the water-wheel in connexion with the low service, and the water to both services had been that of the old well.

On further investigation, however, it was found that some water from the new well, raised on or before August 1st, had been stored in the new high service reservoir, and that on August 17th, the waterwheel being on that day under repair, this stored water was distributed to the high service houses of the town. It was distributed on no other day and to no other houses. These 330 houses therefore on which the fever almost exclusively fell had received a different water from the other houses of the town, viz., water from the new well, stored up from August 1st, and delivered on August 17th. The statement may be repeated that no other condition could be found, on careful and detailed inquiry, at all coincident with the outbreak of fever.

Analyses of several waters of Guildford, including that which the circumstances mentioned had brought under suspicion, have been made for this report by Prof. Miller. The results with Dr. Miller's comments on them are subjoined.

"Four samples of waters were received duly secured in stoppered glass bottles, and labelled as follows:—

1. Old well, Guildford, September 26, 1867.
2. New well, Guildford, September 26, 1867.
3. Mill Tail, Guildford, September 26, 1867.
4. Guildford new reservoir, October 1.

In the first three samples there was an extremely scanty reddish sediment; the fourth sample was quite bright. No sensible colour, smell, or taste was exhibited in any of the samples, except that from the mill tail, which had a faint yellowish tinge and a slightly musty taste. They are chalk waters and soften considerably on boiling; and like most chalk springs seems to soften by exposure to the air. That from the reservoir, where it had been standing for two months as Dr. Buchanan informs us, is considerably softer than that taken newly from the well.

There is nothing remarkable in the amount or quality of the saline matter, a little ammonia and a small amount of nitrates are present: the ammonia derived probably from surface drainage; it is distinctly more in the new well water than in the old. The amount of nitrates is small in all cases. So also is the quantity of organic matter, which however, is decidedly greater in the new than in the old well. After standing in the reservoir for some weeks it appears, as is usual in such cases, to have undergone a partial oxidation, the quantity of nitrates having increased, whilst that of the ammonia and organic matter has distinctly diminished.

The aeration of the water from the old well is perfect; *that from the new well very defective.* But this water after it has stood in the reservoir (specimen No. 4.) has nearly recovered its proper proportion of oxygen. The water from the new well, No. 2, appears to have contained some putrescible or rapidly alterable substance, which has absorbed a large quantity of the dissolved oxygen which spring water ought to contain.

I subjoin details of the analyses :—

Guildford Waters.	1 Old Well.	2 New Well.	3 Mill Tail.	4 New Reservoir.
Appearance	Nearly bright.			Bright.
Colour	—	—	Slight yellowish	—
Taste and smell	None.	None.	Slight musty.	None.
Clark's Scale. Hardness before boiling	15°·1	16°·2	8°·7	10°·7
Clark's Scale. Hardness after boiling one hour	4°·8	4°·1	3°·9	2°·9
Total solids in grs. per gall.	23·2	24·0	13·4	21·8
Fixed salts	22·7	23·2	12·5	21·4
Volatile and combustible matters	0·5	0·8	0·9	0·4
Nitric acid, N_2O_5	1·20	1·10	0·20	2·05
Ammonia	0·01	0·02	0·01	0·007
Gas in cubic inches per gallon	16·30	19·49	15·22	16·30
Carbonic acid, CO_2	7·74	8·18	4·11	6·19
Oxygen	2·85	1·17	2·89	2·93
Nitrogen	5·71	10·14	8·22	7·18
Ratio of oxygen to nitrogen	1:2·05	1:8·6	1:2·84	1:2·4

Respecting the source from which the water of the new well might have received the impurities detected by Dr. Miller, it was first necessary to consider the accidents to which the well might have been subjected since the time at which its water had been last pumped.* In answer to questions on this point, Dr. Miller has furnished me with the following opinion :—

" I would state in reply to your question, ' Whether the peculiarities ' of water No. 2 from the new well are either wholly or in part accounted ' for, (1.) by the partial stagnation of the water during a period of two ' months ; or (2.) by the entrance of the following substances into the ' well : pieces of wood, oil, cotton-waste used in cleaning machinery ?' That I see nothing contrary to the opinion, that the absorption of oxygen noticed in the analysis should have been occasioned by a partial stagnation of the water in contact with such substances as those above enumerated, particularly the oil and cotton-waste used for lubricating machinery. I should also think it probable that some contamination with animal matter of excrementitious origin had occurred. Though certainly not to any large extent, the presence of ammonia points, however, unmistakeably to this source of contamination."

* The bulk of the water that remained stored in the high service tank on October 1st was, as Professor Miller points out, perfectly clear. But a small quantity containing sediment was procured for me by Mr. Taylor. It showed to the microscope mainly crystals of carbonate of lime with much organic detritus, among which fragments of decomposed dotted, woody fibre were distinguished ; and broken portions of some entomostracean. Nothing was seen resembling a fungus neither in the first deposit nor in the lighter secondary sediment from the water.

The next point for consideration is how excrementitious matters could have got into the new well. Not analysis only, but physical considerations show that the new well is supplied by a different spring in the Chalk from that which feeds the old well: for the old well is unaffected in level when the water of the river is drawn off; the new well is reduced in level on such occasions. Then it is known that the new well gets its water not by percolation only, but from a fissure in the Chalk: for at the time of construction of the new well very little water was obtained, till, somewhat suddenly, an abundant supply was reached, so abundant that the ordinary power of the engine could not empty the well. Now into this fissure or into the Chalk around the well, it was certainly easy for excrementitious impurities to have entered. A sewer runs within 10 feet of the well, through which sewer the iron delivery-pipe of the high service passes. The same intense vibration (alleged to have been due to the want of a valve in some critical situation), which broke down the engine on August 1st, is found to have loosened the bricks in this sewer, and to have caused some escape of its contents, though not to any large extent. The sewer, though in the main receiving surface water only, receives the excreta from certain waterclosets and the overflow of certain cesspools in and about South Street; and into a branch of this sewer in an adjacent alley, just above the fracture, certain privies used by many poor families also discharge the liquid portion of their contents. There is reason to suspect other leakage from these drains and sewers, all of which are on a higher level than the well, and are in close neighbourhood to it.* [*See Postscript.*]

Mr. Taylor and the surveyor have kindly helped me to inquire whether impurities derived from this source of probable contamination could have included in them any specific typhoid matter. It appears that at one house in South Street there was a case of typhoid fever in July under the care of Mr. Sells, but the slops only of this house pass into the sewer and not the matters from the watercloset. In the houses that drain into the sewer and lie near the new well there was typhoid fever a year ago, but none since.†

It here arises to point out that not only this particular new well, but many of the wells of Guildford, must be exposed to danger from sewage

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* There is no chance of impurities having entered the water while it was stored in the new reservoir. This is covered, high on a hill and away from all detectable risk.

† Another suggestion has been made as to sources of impurity in the drinking water of the town. There exists a communication between the river and the pipes of the waterworks. This is said to be very rarely used, and only for the purpose of getting a first sucking power to the pumps; and it is stated not to have been used at all during the present summer. However, since the termination of this inquiry, a specimen of water has been sent to me that was taken direct from the high service mains at Charlotteville; it contains much dark sediment, and shows by the microscope diatomaceæ and other organic forms that have almost certainly been introduced from the river. It will be remembered that the water now being supplied to the high service mains is professedly wholly from the old well. Could some river water, temporarily and even without knowledge, have been on some previous occasion delivered to the high service system? At all events it is to be wished that any communication whatever with the river should for the future be discontinued.

P.S., Dec. 31, 1867. A paragraph in the "Lancet" of November 30th, states that "it is now known that there were not only means of conveying the water of the river Wey into the well supplying the town with water, but that it was the practice three times a week to turn the river water into the well." But according to the most accurate information obtained both at the time of the original inquiry and lately in answer to direct questions it does not appear that there is any foundation for this statement.

contamination, and latterly to a much greater extent than formerly. Until the last few years the ordinary house cesspool into the Chalk received but little liquid matter, but recently the Local Board, with the object of keeping down cesspool emanations, has had the privies converted into trapped waterclosets (still connected with the cesspools) requiring a great deal of water to be thrown down them to keep them clean. No doubt the great advantage of keeping away stinks is procured by this means, but it must be at the cost of saturating the porous soil much more rapidly with the soluble parts of cesspool contents. A risk is thus introduced of passing into the wells incompletely oxidized derivates of excrement; especially if the well be near to a cesspool, or if it be supplied by considerable fissures in the Chalk, would this risk of polluting the wells become formidable.

A point in the natural history of typhoid appears to receive elucidation, if the deductions of this report as to causation are correct. The water which is believed to have been the "cause" of the outbreak was delivered on August 17th, and on that day only. The first cases of the fever came under medical observation on August 28th; after that two or three each day, and a very large number on September 3rd and 4th. With allowance for the varying time that would elapse in various cases between the occurrence of the first symptoms of typhoid and the sending for a doctor there is enough correspondence in these dates to fix the occurrence of the first symptoms in a great proportion of cases on or about August 28th, or 11 days after the operation of the cause. Inasmuch as other cases occurred in considerable numbers for several days after September 4th, it may be that in those cases there was a longer incubation period. This does not, however, upon such information as is available, appear to have been necessarily the case; for many of the high service houses are furnished with cisterns and others with large underground tanks in which the water received on August 17th would be stored; mixed, indeed, more or less with other water delivered before and after, but not necessarily losing any noxious quality it might have possessed until a considerable number of days had elapsed. The houses in Pannell's Terrace were attacked particularly early and suddenly. These have no cisterns, but take their water direct from the mains.

Postscript, December 31.—Mr. Taylor writes, December 21: "I take upon myself to inform you that your suspicions as to the percolation of sewage matters into the new well have been now rendered almost certain. The engineers employed in the repairs of the steam engine noticed some exudation on the wall of the engine house next the alley where the sewer runs, and the pit of the fly-wheel contained a notable quantity of the same. As the exudation had the smell of sewage, the ground was opened in the alley at a point adjacent to the engine house. The sewer was found leaking in various places and the soil between it and the wall of the engine house was saturated with sewage of which as much appeared to run outside as inside the sewer. This was found to be an old-fashioned 12-inch drain constructed with red unglazed gutter tiles, with butt joints and common mortar. The tiles forming the lower half of the cylinder were in places completely worn away, and at one point several feet of them were missing, and the upper tiles had fallen in upon the soil below. All the joints gave exit to water, and the ground was a quagmire of filth beneath and on each side. Dark coloured fetid slush

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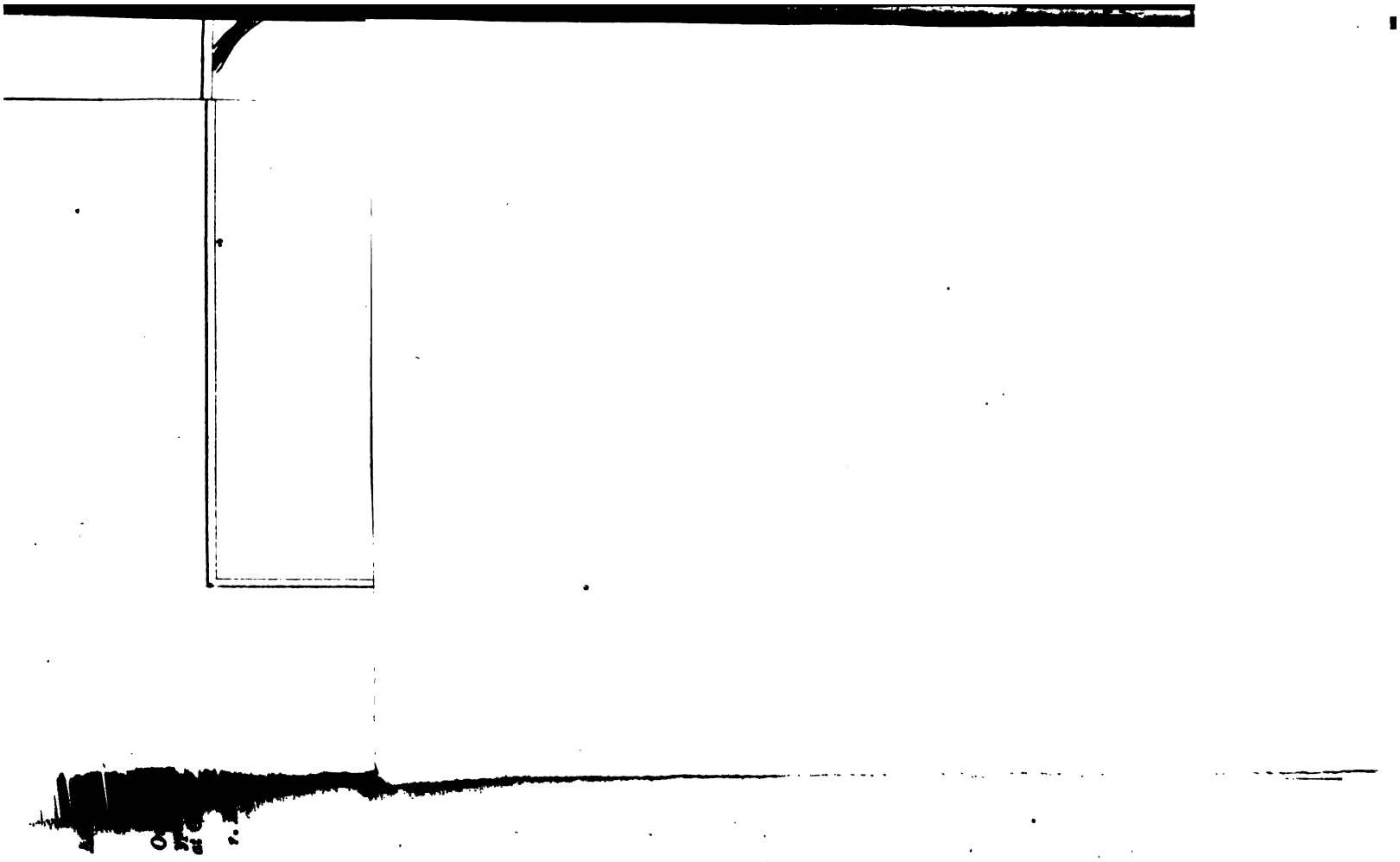


it and and removed in baskets, making the men vomit yed in the work."—Mr. Taylor further informs me that er of deaths from fever, up to the end of the epidemic g three or four who died in other districts after removal and that the last death was on Nov. 22nd. On a rough gives the total number of cases of fever from August to). He mentions that among the few early cases ("less ext, p. 36) of fever which did not appear to be connected high service water supply, he has since learnt that three cluded who shortly before their attack went from their r part of the town to a house within the high-service rank freely of the water supplied to that house; it was ree deaths from fever subsequently occurred.

ETS on an EPIDEMIC of TYPHOID FEVER at TERLING, by Dr. R. THORNE THORNE.

FIRST REPORT.

1868.)—THE Lords of Her Majesty's Council having at a serious and sudden outbreak of fever had occurred f Terling, in Essex, I was instructed by their Medical last of December 1867, to proceed to the spot in order to e causes and nature of the disease. I accordingly on that day, and remained there till the 25th of on the 6th of January I, with renewed instructions, e place, and again remained there until the 13th. I rt the result of my inquiries on those two occasions, and ations which I made to the local authorities.

ated in the Witham Union, and lies four miles to the rn. According to the investigations made by Mr. W. Geological Survey of England, it is placed on a bed of ich comes to the surface at the bottom of a small valley stream flows; on either side it is covered by a plateau occasional beds of sand, on which, with one or two he dwellings stand; further still from the stream, and ge, lie patches of Boulder clay, known locally as Marly ntry for many miles around is generally flat; land t plentiful; water is found in great abundance in ponds y the roadside, and the atmosphere is unusually moist. throughout the county, the smallness and scarcity of w that a great portion of the rain that falls penetrates e village itself, though scattered over an area of several ally collected on the gradually sloping banks of a rivulet which, flowing southwards, empties itself into the Black- ese banks, however, are of a very undulating character. erling Place, the residence of Lord Rayleigh, and the anything but labourers' cottages are to be seen through- and these are almost without exception of the poorest ny are constructed merely of lath and plaster, con- with a thatched roof, and the whole fixed on a basis of rs consist in great part of wood, which is often in a rotten state; some again, of more recent date, are built of brick.

Description of place.

The inhabitants of Terling present many characteristics of great interest. They are all very poor, the general wages for the men, varying year by year from 10*s.* to 12*s.* a week, some receiving 13*s.* and 14*s.*; many seldom taste fresh meat, and a few of them only occasionally procure a piece of bacon or a herring. I saw one Sunday dinner table spread only with carrots, turnips, and a plain dough pudding, even bread was absent. The ordinary dinner consists of bread and cheese.

Characteristics of population.

Socially there is nothing which can tend to raise or elevate the people; no middle-class exists for them to imitate, or to which they can aspire to rise; there is almost a complete gap between the few wealthy residents and the poor labourer. The population is about 900, and for a long time there has been no variation in this number; this I was told has been mainly due to the fact that new-comers have not, as a rule, been well received there, owing to the desire not to increase the parish rates, and the passing of the Union Chargeability Act has not as yet occasioned any difference in this respect. From the description which I received of the villagers it appears also that they have a tendency to isolate themselves, many hardly ever leaving their own parish, even to visit a neighbouring village, and hence they intermarry to such an extent, that "half the people are related to each other." They are intellectually and physically of a low type, there are among them eight or nine idiots and imbecile children, all seem dull of comprehension, and "hardly a well-built man is to be seen." An extraordinarily large number of them are the victims of phthisis and scrofula; this may be partly accounted for by the numerous intermarriages, partly by the moisture of the soil and the atmosphere, and the entire absence of all drainage. Ague was very prevalent throughout the neighbourhood until about the year 1840, but it is now only seen on rare occasions. There is much intemperance in the place, illegitimate children abound, sometimes many in one family, and so distinguishing a merit is it deemed for a girl to marry without being pregnant, that to each such bride, a principal benefactress of the village is in the habit of giving a special wedding gift.

Administration of sanitary law in the place.

At Terling all the nuisances which are generally associated with outbreaks of typhoid fever exist in great and unusual abundance, and all that is necessary to produce contamination of air, soil, and water is to be found throughout the village. The cottages are literally surrounded by every species of nuisance that it is possible to conceive; slops and ashes are thrown down on the unpaved yards and gardens; manure heaps, cesspools, and masses of decaying vegetable matter lie round about. The privies, none of which have a properly constructed tank for the reception of fæcal matter, are in many instances in a most dilapidated state, and owing to their being frequently constructed of wood, the back is in part broken away, and the filth either lies in masses on the ground, or else is collected in large holes which have been dug out for that purpose; and as Lord Rayleigh has granted allotments of ground to his tenants, they cherish and store up these foul accumulations, nominally for the purposes of manure until they assume a magnitude which none but those who have seen them can believe in. Surrounding one cottage, and within a circumference of 20 feet of it, I found one pigstye, three manure heaps, two cesspools, and a privy, the contents of which extended about 12 feet down an adjoining field.

In the central part of the village, each cottage, or each group of two or three, has its own well, and if the ground is at all undulating, it is invariably placed at the lowest point. These wells which are all sunk in the gravel, are as a rule uncovered, and are merely lined with bricks placed loosely one above another, without any cement or plaster; their depth, which varies from about 5 feet to 40 feet, agrees with the

increase in the rise of ground. On a higher level than these wells and everywhere surrounding them, lie the various nuisances just enumerated, and since the soil is of a very loose and porous nature, and one which easily admits of the percolation of fluids, the closeness of such sources of contamination to the cottagers' drinking water is seen to be fraught with the greatest danger. Some of the cottages lying in the outskirts of the village have no wells, and those who reside in them are therefore compelled to fetch their drinking water from ponds in the addjoining fields. All the drainage from the field ditches, and at times from the roadsides runs into them, the cattle frequent them, and in summer they are, to use the expression of a resident, "nothing better than stinking pools." In only one instance did I find that the river water was used for drinking purposes, but in this case at a point where the stream was little better than a sewer.

Prevalence of overcrowding

Overcrowding is almost everywhere met with, and at the present time it exists in its worst form; two and three fever patients are frequently seen lying in one bed, whilst several of their healthy relatives occupy the same room. In one instance I found a woman suffering from the epidemic disease, occupying with six of her family, a bedroom measuring only 10 feet long by 9½ feet broad, and 6 feet high, the chimney was blocked up, and the only window was less than 3 feet square. Here each individual had less than 82 cubic feet of air, and ventilation was, as indeed almost everywhere, entirely neglected.

Description o epidemic.

The epidemic from which Terling is suffering is well marked typhoid fever. Cases of this disease, Dr. Gimson states have been seen about the village for five years (his knowledge does not extend further back), and in Dec. 1862 and the early part of 1863 about 40 cases and five deaths occurred; since then occasional instances have been met with, and during the past year at least one case has been seen every second or third month. The present outbreak is most alarming both in its magnitude and the suddenness of its occurrence. Almost entire families are attacked, a father only remaining in some instances to nurse and attend to his wife and a large family of sick children. The disease is of unusual severity, the characteristic rose spots are very abundant, and hœmorrhage from the bowels exists in a large number of cases; great prostration of the nervous power is evident from the first day of the affection, and in some instances the patient seems to be almost instantly overwhelmed with the intensity of the poison. A woman who is at her washtub one day is dead three days after, a girl strong and hearty at the commencement of the week, passes rapidly into a state of insensibility and dies in a few days, before the special characteristics of the disease have had time to manifest themselves. On the 13th of January 1868, 208 persons had already been attacked by the prevailing malady, and several fresh cases were daily occurring. I do not include in my number cases of so-called diarrhœa (possibly all mild cases of typhoid fever) which were only accidentally heard of and which probably were numerous, though not of sufficient severity, to call for medical relief.

With one exception hereafter to be mentioned, the disease seems to date from Dec. 4th; during the following 10 days 30 fresh cases were seen, but on the 15th, 16th and 17th by far the largest number were attacked, 22, 19 and 12 cases occurring respectively on those days. After this though the daily number of fresh cases was by no means so large, still a steady increase took place. The villagers were everywhere alarmed, for owing to the many intermarriages, everyone had several

relatives attacked, some dangerously so. As yet, however, only one death had taken place, namely on Dec. 14th; but, when the third week of the epidemic had arrived a steady and gradually increasing death rate commenced, and on the 30th, twelve of the patients had died, and others were dying. Terling was now completely panic-stricken, and the moral effect of the tolling of the church bell at the death and funeral of the parishioners seemed so prejudicial not only to the sick but also to those who still remained unaffected, that I thought it right to suggest to the vicar the immediate discontinuance of that ordinary custom. Women with tears flowing down their cheeks called from their cottage doors for help, and everyone seemed to dread the prevailing disease. No class of persons was exempt; the rich, the well fed and clad, were attacked in common with the poor and destitute. At Lord Rayleigh's residence 10 cases had occurred, the Vicar's house was a seat of the epidemic, and from one end of the village to the other, the disease seemed to be almost evenly spread.

Effect of age and sex on epidemic.

Age and sex seemed to present remarkable peculiarities, thus: out of 145 cases whose ages I was enabled to obtain, 79 were children under 14 years of age, and of the remaining 66, 50 were females, leaving only 16 males whose ages exceeded 14 years, out of the entire number attacked. This I believe is to be accounted for by the fact that the men and the majority of the boys over 14 years of age, spend the greater portion of their time away from home, labouring in the fields, and that they principally drink beer, whereas the women and children are left at home, and procure a considerable portion of their beverage from the wells; the children drinking directly from them much more frequently than the women, owing to the latter consuming a good deal of tea, in making which the water is of course boiled.

Description of first case of typhoid fever.

The first case of typhoid fever which has occurred in Terling for two or three months, is that of a young woman who lives at Lord Rayleigh's dairy (vide map, A), and the attack, in this instance commenced on the 13th of November. A month previous to her attack however, it appears that she had just returned from Somersetshire, and a few days after her arrival at home, she was seized with diarrhœa, or as she terms it, "a bilous attack," which she thought was induced by drinking beer, after having for some time been accustomed to cider. This indisposition lasted for about three days, and then passed off; but three weeks afterwards, however, an unmistakeable attack of typhoid fever, marked with an abundant eruption of rose spots, and severe hœmorrhage from the bowels commenced. When I first saw her on December 22d, her bowel-symptoms had but recently ceased, and she was still in a very prostrate condition. This patient, in common with her father and mother, procures all her drinking water from the river which flows by the side of their house. The water, which has a very dirty appearance, is collected at the foot of a few steps leading from a yard down to the stream. Three feet from this spot, a pipe which conveys all the drainage from the yard and the wash-house, empties itself into the river, and 12 yards lower down the stream is the privy which belongs to the dairy, the entire contents of which fall into the water. On making inquiries, I found from those who lived here, that at times, owing to the scarcity of water, the river at this spot is in nearly a stagnant condition, and the water must therefore under these circumstances become well saturated with fæcal matter, to say nothing of the surface drainage. But in addition to this, the dairy lies at the extreme south of the village, and since the stream flows towards it, the contents of several ditches which I saw passing from privies to the water's edge, must

be washed past the very spot where these persons collect their drinking water. It becomes a question whether this young woman could have imported the fever from Somersetshire, and whether the diarrhœa which occurred immediately after her arrival at Terling, was not a part of the disease which, after apparently subsiding, manifested itself again three weeks afterwards; she, however, had certainly not to her knowledge been amongst persons who were suffering from any disease at all. It is also possible that her fever may have been brought on through drinking contaminated water, although the mother of the patient assured me that it was always boiled before anyone used it.

I made careful inquiries, in order to ascertain whether it was possible that the milk supplied from this dairy, could, after having been diluted with the river water, have caused the general outbreak. Nothing, however, seemed to support this idea, for the milk is the property of Lord Rayleigh, and the dairy-woman receives from him a weekly stipend quite irrespective of the quantity of milk which she sells. The majority of the villagers drink skimmed milk which they obtain at a nominal price, and it is evident that by adding water to it, the dairy-woman would only be giving herself additional trouble, without being in any way a gainer, and her denial of such a practice is all the more to be depended on, because the inhabitants of those cottages where there has been no disease during the epidemic, get their milk from this dairy as well as those amongst whom typhoid fever has been so prevalent.

Connexion of epidemic with variations in height of surface water.

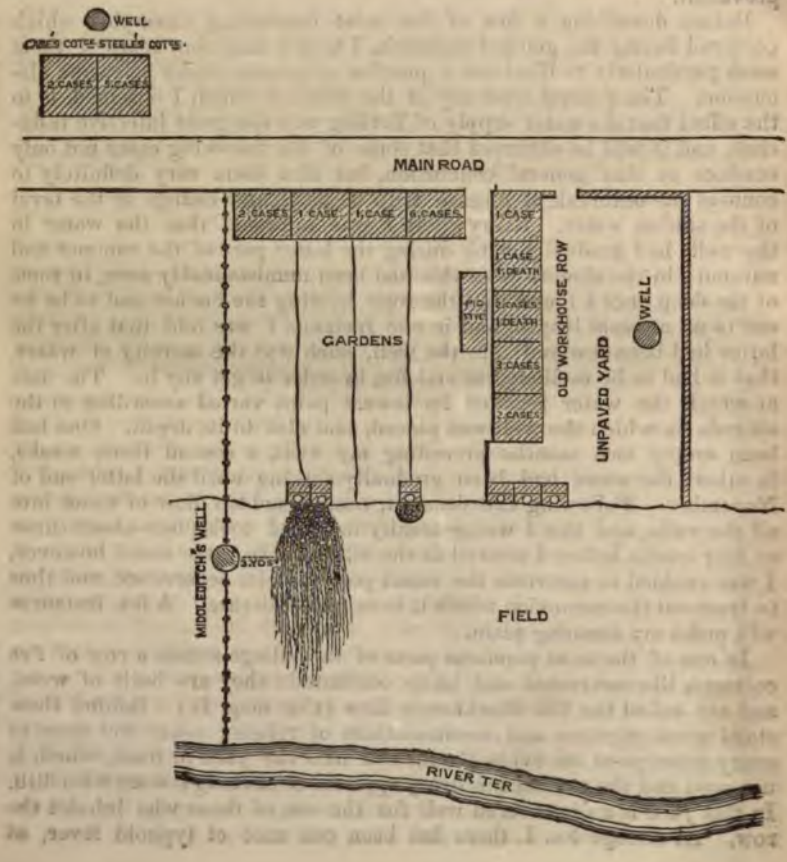
Before describing a few of the most interesting examples which occurred during the general outbreak, I would note that some of them seem particularly to illustrate a question at present under scientific discussion. The general tendency of the evidence which I obtained, is to the effect that the water supply of Terling was the great infective influence, and it will be observed that some of the following cases not only conduce to that general conclusion, but also seem very definitely to connect the outbreak of disease with a particular change in the level of the surface water. Everywhere I was informed that the water in the wells had gradually sunk during the latter part of the summer and autumn; in the shallow ones this had been unmistakeably seen, in some of the deep ones I found that the rope holding the bucket had to be let out to an unusual length, and in one instance I was told that after the latter had been lowered into the well, such was the scarcity of water, that it had to be oscillated to and fro, in order to get any in. The date at which the water reached its lowest point varied according to the altitude on which the well was placed, and also to its depth. One had been empty two months preceding my visit, a second three weeks, in others the water had been gradually sinking until the latter end of November. Following this drought, came a sudden flow of water into all the wells, and this I was generally informed took place about three or four weeks before I arrived at the village. In three cases, however, I was enabled to ascertain the exact period of its occurrence, and thus to trace out the connexion which it bore to the disease. A few instances will make my meaning plain.

Illustrations of the circumstances of the attack.

In one of the most populous parts of the village stands a row of five cottages, ill-constructed and badly ventilated; they are built of wood, and are called the Old Workhouse Row (vide map, B.) Behind them stand some pigstyes and accumulations of refuse; ashes and slops of every description are evidently thrown into the yard in front, which is unpaved and the ground has every appearance of being sodden with filth. In this yard is an uncovered well for the use of those who inhabit the row. At cottage No. I. there has been one case of typhoid fever, at

Illustrations of the circumstances of the attack.

No. II. one case and one death, at No. III. two cases and one death, at No. IV. three cases, and at No. V. two cases. The water in the well I ascertained had very gradually sunk during the summer, and after having remained empty for about two months, during which time all those living here procured their water from a neighbouring well, bearing the name of "Middleditch's well," (vide map, C), it rose again towards the end of November. A woman living in the first cottage was delivered of a child on the 19th of November, and she experienced considerable inconvenience owing to there being no water at hand with which her linen could be washed. Exactly one week after the birth of her infant, that is to say on the 26th of November, water was again found in the well, it was immediately procured for the use of her house, and it was also on that day used for drinking purposes. The first case of fever in this row occurred in this woman's family on the 6th of December, 10 days after the rising of the surface water, or in other words, the period which elapsed between that event and the outbreak of the disease corresponds to what is generally admitted to be about the period of incubation for typhoid fever. On the 9th of December, two more cases occurred in this same block of cottages, another on December the 12th, and three more on the 15th At first sight the connexion between these latter cases and the rise of the water seemed to be less distinct, but on inquiring more minutely into the matter, I ascertained that in all the other cottages, although



the water was used for scouring the floors from the first, yet, owing to its not having its normal bright and clear appearance, all the drinking water was brought up from Middleditch's well for several days longer, but the exact number of days I was in no instance able to ascertain.

Another instance in every respect similar to this one is that of two cottages occupied by families named Steele and Game, close to the Old Workhouse Row (vide map, F); their common well having been empty for three weeks, they also sought their water from Middleditch's. Seven cases of typhoid fever have occurred here, and though perfectly accurate dates could not be ascertained, the disease had evidently broken out about a fortnight after they were first able to procure water on their own premises. Standing again close to the Old Workhouse Row, and at right angles to it are four cottages, in the first of which six have been affected, in the second there has been one case, in the third two cases, and in the fourth two cases. These cottages have gardens behind them, at the end of which are situated three privies, one stands alone, and its entire contents are collected in a huge hole behind it in an adjoining field, the other two stand together and empty their contents on to the same field. Into one of these a very large amount of soapsuds and water is daily thrown from a wash-house, these become mixed with the fæcal matter, and the whole runs in a large mass, which subsequently divides into several streams for about 20 yards down the field which slopes towards the river. This portion of the field is so saturated with fæcal matter as to be converted into a foul swamp, which I found it impossible to walk across. Three yards from the margin of this flow of filth, and at a very much lower level is the well referred to as "Middleditch's. It is about 5 feet deep, and owing to its very low situation it is never known to be empty. This well supplies the four cottages just mentioned, and it is impossible that it can be otherwise than seriously contaminated by the fæcal matter running from the above-named privies, indeed from its position it is evident that the water supplying it must pass through the very ground into which the filth sinks, and hence it becomes in plain terms a filtrate of human excrement.

The question now arises, was the contaminated state of this water during the period of scarcity the cause of the fever in the Old Workhouse Row, and in the cottages occupied by Steele and Game? This may fairly be answered in the negative, first, because none of the cases occurred during or immediately after the period in which it was used by those living in these places, and secondly, because the first symptoms of the disease corresponded with the time at which they all discontinued using it, owing to their being able to procure water from their own wells. But the outbreak in the four cottages at right angles to the Old Workhouse Row has still to be accounted for. Now, although I was unable to get distinct proof that any change had occurred in the height of the water in Middleditch's well, we may conclude that it did not form an exception to the general rule everywhere else observed, and the propriety of this conclusion is confirmed by the fact that in the case of a well called "Lines' Well," (vide map, D), which is situated on even a slightly lower level than Middleditch's, and like it is never known to be empty, the fall and the rise of the water were observed to take place, although not to so considerable an extent as in wells which were placed on higher ground.

In another part of the village are two cottages, the first of which is occupied by a family named Aves, and where I saw five well-marked cases of typhoid fever, in the second I saw one (vide map, E). About 10 feet from these cottages and in a garden belonging to them is

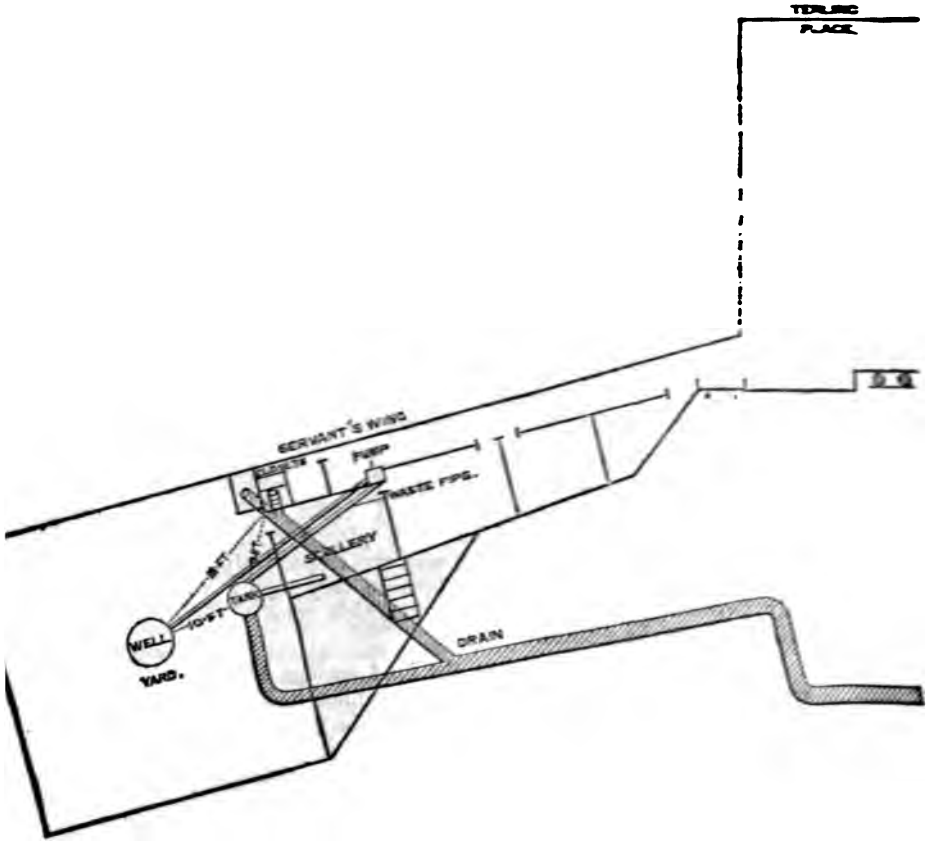
Illustrations of the circumstances of the attack.

situated the well ; 20 feet from this well is a deep cesspool loosely lined with bricks which contains the drainage from the privies of an adjoining large house, and within 12 feet of it a privy which pours its contents into a second cesspool. The water in the well I was informed had been exceedingly low, especially about the 20th of November. The woman from whom I derived this information, and who lives in the first-named cottage was taken ill a few days after this date, and was unable to leave the house for an entire week. Almost the first time she ventured out she went to the well, and she remembers being surprised that the amount of water in it had so greatly increased during her short illness. This visit to the well, took place about the 29th of November, but my informant not being able to speak with perfect accuracy, it may have occurred one day prior to, or subsequent to that date. The first case of typhoid fever in her cottage was that of her daughter Susan Aves, who was attacked on the 16th of December, and whom I saw apparently in a dying condition ; four others occurred soon after.

One more instance also tends to the same conclusion. A family named Edwards live in a cottage near the river, and two of their number were suffering from typhoid fever at the time of my visit. Their well is placed in a garden by the side of their house. From this well, which is at about the lowest point, the ground gradually rises in almost every direction, and within 26 feet of it there are two manure heaps with a cesspool between them, and three privies, two of which belong to some neighbouring cottages. Behind each of these privies is a hole in the ground for the reception of their contents ; this receptacle in the case of the central one is of an enormous magnitude, measuring about 12 feet broad by 15 feet long, and so crammed is it with fæcal matter that its contents have been poured a few feet down an incline, and have there burrowed out a second cesspool nearly 12 feet long by 8 in breadth. In addition to the above-named nuisances a pigstye is also placed near the well though on a slightly lower level. This well which has been referred to as "Lines' Well," and which is about 5 feet deep, is lined with bricks simply placed one above another, and the edges of these bricks have a blackened appearance. It lies very low, and consequently is never empty, but it is evident that the height of the water in it has participated in the change everywhere else observed, for when speaking of its appearance being turbid, I was informed that this was due to the well having recently been suddenly filled. No one could give me the exact date of this occurrence, but I ascertained that it took place at about the same time that it was observed in the other wells in the village.

One more example is worthy of detail, owing to the fact that the spot which was attacked was an almost isolated one, the patients also were all living, surrounded by comfort and plenty, and apparently placed under the most perfect hygienic conditions. Ten cases of typhoid fever have occurred at Terling Place, which is situated on an estate lying at the extreme south of the village. Here, as elsewhere, the severity of the disease has been very great, four of the patients having suffered seriously from hœmorrhage from the bowels, and three have died. All of those affected were servants residing in the establishment, and although they occasionally frequented the village, in no instance could I ascertain that they had drunk any water from the wells. The portion of Lord Rayleigh's residence occupied by the servants is a wing almost entirely detached from the house, only communicating with it by a small door. In endeavouring to ascertain the cause of the

disease here, I naturally turned my attention to this part of the building. At the end of a long passage stands a pump, the water from which is only used by one member of the household with the exception of the servants. This pump is supplied from a well 40 feet deep which is situated in a courtyard at the end of the servants' wing, and the pipe which passes from the well to the pump crosses a brick drain leading from two water-closets. This pipe which is a leaden one I found to be perfectly sound throughout. The drain was then opened, and on examining it, it was evident that the mortar which was used to cement the bricks together was almost destroyed, and at the side of the drain which is nearest the well, a leakage had evidently taken place into the surrounding ground, which had a fæcal odour. Nine feet from the drain and about midway between it and the well is a bricked cesspool



or tank, which ought only to receive the dirty water from the scullery, the waste water from the pump, and the rain from a portion of the roof On opening it, however, I was struck, as was also a servant who accompanied me, with the fact that the odour was most distinctly of a fæcal character. The distance from the drain to the well is 18 feet, and the soil here as elsewhere is loose gravel, and easily allows

Illustrations of the circumstances of the attack.

of the passage of contaminating matters. This well might have become fouled either directly by the leakage from the drain, or indirectly by the passage of the foul fluids first into the cesspool, which is not watertight, and then from it on to the well. One point worthy of remark is that the outbreak at Terling Place occurred simultaneously with that throughout the village, and we may fairly assume that the water in the well here had risen at the same time with that in the other wells, although, owing to its being a covered one, this fact had escaped observation. I would, however, state that a very bad odour had been noticed to rise up the waste-pipe leading from the pump to the tank in the yard; this for some weeks had been complained of in the servant's wing, and by some residing here, was considered to be the cause of the fever. The leakage from the drain into the tank could easily have given rise to this odour.

On the outskirts of the village, as already mentioned, the cottagers in many instances procure their water from the neighbouring ponds, and here it was in many cases not easy to ascertain the exact source of the disease, my difficulty in this respect being much increased by the low intelligence of the people. In some families, however, children only were attacked, in others the children had been attacked first. These all daily attend the village school, and those who live some distance from it do not return home in the middle of the day for dinner, but they take a piece of bread and cheese with them in their pockets, and procure water where they best can; some drink from the school pump, others naturally run about the village with their companions and therefore would be almost sure to frequent some of the wells which are undoubtedly contaminated. I found that the source from which this school derives its water was a well placed in such a position as to forbid the idea of any possible contamination. A leaden pipe, however, leading from it to the pump passes only 6 feet from a cesspool, but had not so far as I could ascertain any defect in it; this pipe will, by my advice be conducted to the pump by a safer route.

During my visit I carefully examined every well throughout the village, and I found that with very few exceptions they were all so placed that the water they contained could easily become contaminated. Two of those which were placed under the exceptional circumstances, and which on the map are respectively indicated by the letters G and H, deserve notice, because they supply with water the only two large groups of cottages in which none of the inmates have suffered from the disease.

It is evident that for years the land springs supplying the village must have washed the foul materials which had soaked through the ground into the wells, although, owing to the water being very abundant, the contaminated solution thus formed was very much diluted. In connexion with this I would call attention to the statement which I have made to the effect that typhoid fever had existed in Terling for at least five years. Recently, however, although the soakage of filth into the ground has been going on, there has been a deficiency in the water supply; that filth must therefore have accumulated until the rise in the surface water took place, when the whole would naturally be washed from the surrounding ground into the wells, and thus give rise to an intensely saturated solution. Great interest, therefore attaches to the ætiological relation which exists between this very severe epidemic of typhoid fever and the state of the water supply: and it deserves the more notice because the facts observed are not in accordance with those

[illegible] the disease [illegible] regarding a [illegible]

[illegible] Old Warehouse Law [illegible] Game: and [illegible] ascertain the [illegible] destined and [illegible] in the [illegible] the rise of the [illegible] occasional [illegible] born [illegible] important [illegible] surface [illegible] period [illegible]

The [illegible] Governors of the [illegible] be seen that [illegible] of Lieutenant [illegible] to them the [illegible] Terling, and pursuing a [illegible] of private and [illegible] could possibly be [illegible] importance of [illegible] be removed after [illegible] should be made [illegible] means should [illegible] The Board [illegible] given, and immediately [illegible] which was [illegible] minutes. Permission [illegible] chamber the [illegible] amount which they [illegible] effectually [illegible] the best [illegible] curious and [illegible] adopting them [illegible] the 14th of January 1818, [illegible] Governors, and [illegible] attention to the [illegible] of disinfection they had [illegible] minutes stating the [illegible] they had taken to [illegible] the disease had [illegible] full to the brim, and [illegible]

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* Professor Bain, in an article published in No. 1 of the *Zoologist* for January 1843, on aquatic Mammalia, says with regard to the water ordinarily found within the pectoral fins, that the supposition of the ordinary supply from the ingestion of the fluid, but from what the water must be very inadequate for the quantity of the water thus quickly thrown out of the spiracle.

† There is the surface water on the other hand, a fall of rain, or in the autumn of snow; but no accompanying observations having been taken at the spot, I am unable to speak with perfect accuracy on this point.

I explained to them, that, had they originally performed their duty as a nuisance authority, the epidemic in Terling would never have occurred, and the lives of the villagers would have been spared, and that therefore, the least which could now be expected of them was an energetic performance of their every day duty. The necessary works to supply pure drinking water had been ordered by the vestry of Terling in consequence of a letter which, in accordance with my instructions I had addressed to them; and by way of preventing a recurrence of this disease by the well-water becoming saturated with the contents of privies, Lord Rayleigh informed me that he was supplying all his cottages, that is to say, 78 out of the 164 in the village, with properly constructed bricked cesspools lined with cement, and effectually covered over.

ACCOUNT by PROFESSOR MILLER, F.R.S., of KING'S COLLEGE, LONDON, of four specimens of TERLING WATER, namely :—

1. Water from Middleditch's well, Terling.
2. Water from village school, Terling.
3. Water from Lines well, Terling.
4. Water from the pump at Terling Place.

Of these waters, No. 2 may be said to be unobjectionable. It is a chalk water which softens considerably on boiling; contains no sensible quantity of ammonia or nitric acid, and is nearly free from chlorides; the amount of organic matter is but small, and it exerts very little reducing action upon the permanganate of potash.

In point of quality, No. 4 comes next. It is not a first-class water. It contains a considerable amount of organic matter, though not in an active state, as it exerts but little reducing effect upon the permanganate. The quantity of ammonia is insignificant, but that of nitrates is more important. The quantity of sulphates and chlorides is small, but though less hard before boiling than No. 2, it does not soften so completely on boiling. The aeration is less perfect than that of No. 2.

No. 1 is a bad water. It contains a large proportion of nitrates, and of ammonia, the quantity of chlorides is considerable, and these three circumstances point to contamination with animal refuse. The amount of organic matter is not large, but it appears to be in an active state of decomposition, as it rapidly reduces the solution of the permanganate. The aeration is imperfect.

No. 3 is a water analogous to No. 1, perhaps not quite so objectionable, as it contains less nitrates and ammonia. On the other hand the proportion of organic matter is large, and it exerts a considerable reducing action on the permanganate. The amount of chlorides is considerable, and nearly all the lime is in the form of sulphates. It scarcely softens at all on boiling; aeration defective.

I may remark that the use of permanganate of potash in such cases is valuable as a qualitative, not as a quantitative test. If a reducing action on this agent is manifest, the water is to be suspected, though not condemned, unless the suspicion is confirmed by other tests. If the permanganate is not reduced there is but little to fear from the organic matter.

I subjoin details of the analyses :—

TERLING WATERS.	1 Middle-ditch.	2 School.	3 Lines.	4 Terling Place.
Colour in 2ft. tube	Greenish yellow.		Greenish yellow.	
Sediment	Consid. brown.	Clear, a few flakes	Distinct brown.	Clear, a few flakes
Odour	None perceptible when warmed.			
Taste	None perceptible.			
Hardness before boiling	25°·6	24°·8	18°·2	15°·3
Do. after boiling 1 hour	16°·5	4°·6	17°·4	7°·2
Total solids in grs. per Imperial gallon	51·9	27·1	38·6	25·7
Fixed salts	50·3	25·6	36·2	23·2
Volatile and combustible	1·6	1·5	2·4	2·5
Nitric Acid	6·67	Trace.	2·56	3·05
Ammonia	0·04	None	Traces.	None.
Action on permanganate of potash	Consider-able.	Very little.	Consider-able.	Little.
Cubic inch of gas per gallon	22·82	15·0	9·0	12·0
Consisting of Carbonic acid	9·57	6·35	3·6	6·00
Consisting of Oxygen	3·08	2·31	0·9	1·38
Consisting of Nitrogen	10·17	6·34	4·5	4·62
Ratio of O:N	1:3·3	1:2·75	1:5	1:3·3

SECOND REPORT (Feb. 4th, 1868.)

Present state of epidemic.

On the 29th of January, in accordance with renewed instructions, I returned to Terling to report again on the state of the epidemic and to ascertain what steps were being taken by the authorities to ensure the abatement of the disease. I found that new cases of fever had continued to arise since my last visit, and that up to the 31st of January at least 260 cases had occurred; the women and children were no longer the principal victims, for many of the able-bodied men and boys were now suffering from the fever. Almost all of these having relatives ill, were exposed to poisonous influences, and the necessarily contaminated state of the atmosphere would easily account for the disease amongst the remainder. The entire number of deaths up to this date was 28, but it is to be feared that others will yet succumb to the disorder. At the same time I am glad to be able to report that the epidemic seems now to have begun to decrease for since the 26th of January only one person has been attacked,

and Dr. Gimson of opinion that the more recent cases are of a decidedly milder type than those with which the epidemic commenced.

Notwithstanding that the urgency of very immediate and prompt action had been again and again pressed upon the Board of Guardians, I still found abominable nuisances in Terling, and it is hardly possible to speak in sufficiently strong terms of the culpable neglect shown by that authority. Fortunately the vestry of the parish (the Sewer Authority), acting under Sec. 11. of the Sanitary Act 1866, had in three of the most populous parts of the village provided a pure water supply for the inhabitants; but to give an example of the mode in which the Board omitted to perform their ordinary duties, even when the villagers were dying around them, I would call attention to a nuisance of colossal magnitude situated behind some cottages on the Upper Green. Within about ten or twelve feet of the back doors and windows of the cottages in question, is a large ditch in one place nearly two yards broad, full of stagnant fluid. Over this ditch four wooden privies are placed, and their entire contents fall into it; the floor in one of them is nearly broken away. All the slops from these cottages are also poured into the ditch, and for a space of between fifty and sixty yards, a foul urinous fluid with fæcal matter floating on its surface, lay soaking into the porous soil on which the cottages are built, and emitting a stench which I, in common with two companions easily detected at a distance of 100 yards. This abominable nuisance has been the subject of much discussion; twice I formally brought it under the notice of the Board, and on two occasions I pointed it out to the officers of the authorities, especially on account of the existence of fever in the adjoining cottages, but, unfortunately, on the 29th of January it was in the same state as when I first drew attention to it. Evidently the main object at which this local authority has aimed is not so much to remove with an exemplary haste all possible sources of disease in Terling, as to give the public an impression that it has already done so; whereas, in reality, the present sanitary condition of the village would be disgraceful, even if this vast epidemic had not rooted itself so deeply on the spot. In no single instance could I ascertain that the Board of Guardians had been instrumental in causing a properly constructed cesspool to be made.

Neglect of duty on the part of the nuisance authority.

Fortunately for the villagers immense private efforts have been made for their relief. Terling Place has been, to use the expression of an inhabitant, "an open house"; wine, brandy, beef tea, milk, and luxuries have been liberally supplied from that residence, and Dr. Gimson who has without official obligation, given up almost all his time in attending to the sick, informed me that, at Lord and Lady Rayleigh's expense, the poor were provided with every requisite, and had their linen washed for them. In addition to this, as the Nuisance Authority had made no attempt to remedy the overcrowding, Lord Rayleigh had fitted up the village school as a convalescent hospital for children; these were brought to it in a covered waggon, and on their arrival they were stripped and washed, then entirely reclothed with garments provided by private individuals, and placed under the care of a lady nurse. Sisters from St. Magaret's Home, East Grinstead, were superintending the nursing throughout the village, and spending their nights with the most dangerous cases.

Relief from private sources.

It is to be hoped that the experience which has in Terling been so dearly bought will not be without effect on the future administration of sanitary law in this district. Measures should at once be adopted which will in future years prevent so devastating an outbreak of disease; the

whole system of cottage accommodation requires re-modelling, and, above all, the cottages should be periodically inspected by a competent person, in order to prevent the unrestricted flourishing of nuisances around the dwellings.

I was also instructed to ascertain, before concluding my visit, whether the other towns and villages belonging to the Witham Union were in a similar insanitary condition to that in which I found Terling, and with this view I spent a few hours in Witham, Great Coggeshall, Messing, and Hatfield Peveril.

Sanitary condition of Witham.

Witham is a small town, containing about 3,500 inhabitants, and is the only place in this Union which is governed by a Local Board of Health. The main streets have an appearance of great cleanliness and comfort, but on passing from them into courts and slums which are hidden from the general view; cesspools, dilapidated privies, with their contents running about the yards and gardens, heaps of decaying animal and vegetable matter, and every species of nuisance can be found in abundance. Some of the inhabitants live in hovels of the most miserable description, where they are surrounded by intolerable stenches, and, I was informed that they dare not complain to their landlords or to the Inspector of Nuisances of the filthiness around them, for if they go to the former, they fear that he will turn them out of their houses, whereas the latter is the relieving officer, and it is their belief that any complaints made to him would go far to prevent their receiving parish relief. But a more serious obstacle even than this exists to any sanitary improvement. Many of the properties on which the worst nuisances exist belong to members of the Local Board, and I would especially allude to several groups of cottages belonging to a Mr. Tomasin, the stinking nuisances around which render them unfit for human habitation. Mr. Tomasin is a gentleman of large fortune, he has a seat at the Local Board, and yet, so much has he neglected the dwellings of the poor which belong to him, that the magistrates have been compelled to summon him before them, in order to force him to remove nuisances on his cottage property. In this town there is, as a rule, a common water supply for several cottages, and the wells are generally protected from contaminating influences. Witham has no system of drainage, but in all probability one will before long be constructed. It is an unhealthy town, and though there has been no special prevalence of specific fevers, still I am informed that disease here assumes a low type, and that strumous affections, rickets and phthisis, attack a large number of the inhabitants.

Sanitary condition of Great Coggeshall.

Great Coggeshall is a small town of about 3,680 inhabitants, and though in a considerably better sanitary state than either Terling or Witham, many portions of it are in a very dirty condition. The inhabitants consist principally of weavers, and, owing to great depression in the trade, they are mostly in a very destitute state. I found no open cesspools in the place, and the privies are periodically inspected and emptied, but ashes, slops, and filth, are generally thrown indiscriminately about the courts and yards. Five years ago about 200 cases of scarlet fever, and 30 deaths took place; and the parish doctor informed me that last year nearly 100 cases of smallpox occurred in the town. The water supply seemed pure, the larger portion of the town being supplied from a public well, called St. Peter's Well, the water from which is conveyed by means of pipes to open reservoirs and pumps in the most populous districts.

Sanitary condition of Messing.

Messing is a small village, containing rather over 800 inhabitants, and may be considered now to be in a moderately good sanitary condition.

This state is, however, only due to a severe outbreak of "fever" which occurred four years ago, and which caused, as I was informed, as many as 23 deaths; nuisances were then rapidly cleared away, privy accommodation was improved, and many of the wells were closed. The inhabitants now procure their drinking water from pumps giving a pure supply.

Sanitary condition of Hatfield Peveril.

Hatfield Peveril, the last village which I visited, and which contains about 1,310 inhabitants, has up to the last few weeks been in a disgraceful sanitary condition; a committee has, however, since the outbreak of the epidemic in Terling, been appointed to improve its state, and this step has been taken none too early, for typhoid fever a few years ago prevailed very extensively amongst the inhabitants, and from personal observation I can say that, up to a very recent date all the predisposing causes of that disease existed abundantly in the village, and that the exciting cause was alone required to produce another outbreak. Here as in the other portions of this district it will be seen that proper sanitary measures have been neglected, until the prevalence of some fearful disease has awakened the authorities to a sense of their duty.

State of surface water throughout the Witham Union.

It is interesting to note that the sudden rise in the surface-water which seemed so clearly to bear upon the outbreak of typhoid fever in Terling, had not been noticed in any of the other portions of the Witham Union which I visited, and in which I did not find that there had been any scarcity of water during the summer and autumn of last year. The absence in these places of the undulations of the surface, so common in Terling, may have some effect in causing this difference, so also may the difference of the superficial soils; thus, at least in some parts of Great Coggeshall only about two or three feet of gravel lie over a yellow clay, locally called Loom, and at all times of the year an abundance of water can be found in this gravel; St. Peter's Well, which supplies so large a portion of the town, is only between two and three feet deep. Thus that which overwhelming evidence has compelled me to consider as of the greatest importance in the vast but isolated outbreak of typhoid fever in Terling, I find has been confined to that village, and has not existed generally throughout the uninfected districts.

Postscript: (March 10th, 1868.)—According to information received since writing the above reports, I am able to state that the epidemic has almost entirely subsided, only one or two fresh cases having occurred during each of the last two weeks. The number of deaths up to March 7th was 41; the anual death-rate being 16.

A communication which I have received from the Rev. F. T. Hill, vicar of Terling, is of considerable interest because it affords additional proof that the well water has been the cause of the outbreak. He informs me that on the outskirts of the village there are 71 persons who procure their drinking water from ponds. Only six cases of typhoid fever have occurred amongst them, and of this number four had been in the habit of frequenting the village; three being children who attended the village school, and the fourth, a man who had been temporarily engaged there as a carpenter.

No. 5.—Report by Dr. Buchanan on the Distribution of Phthisis as affected by Dampness of Soil.

N.B. The Maps illustrating this Report are at the end of the Volume.

The general sanitary inquiry which was entrusted to me last year having appeared to show a relation between wetness of soil and prevalence of consumption, the subject is now further examined with direct reference to geological considerations. The results obtained from this new basis of inquiry turn out to be definite and confirmatory of the conclusions provisionally arrived at last year.

Materials for inquiry.

The Geological Survey of England, advancing to completeness in its records of the great formations of the country, has hitherto mapped the minute surface geology only in the counties of Surrey, Kent, and Sussex. From the present point of view it is plain that surface peculiarities must be taken into account quite as much as the great divisions of the geologist—that brick earth, drift gravel, river alluvium, and the like, have an importance in themselves apart from the character of the larger formations over which they lie. The three south-eastern counties, therefore, form the only area where the Survey yet affords materials for profitable detailed examination of soil as affecting the health of residents on it; and the present report will concern itself exclusively with them.* It happens that there is no part of England better adapted to the enquiry—in which varieties of soil would be greater, and differences of other sorts less obtrusive.

The materials for the present report have been (1) the Parliamentary Return, No. 12, Session 1863, which furnishes for each registration district the death-rate from consumption in the mean of the 10 years 1851–60; (2) local inquiries that were necessary to correct the registered death-rates of particular districts; (3) the census returns of 1841–51–61; (4) the maps of the tithe survey, which give the boundaries of the several parishes comprised in each registration district; (5) the maps of the Geological Survey, with various unpublished sections and other documents placed at the disposal of this report by the Director-General; and (6) minute information about the topography and geology of particular districts supplied by Mr. Whitaker and Mr. Topley, two of the geologists who have actually worked the three counties under examination; and (7) information from medical practitioners, surveyors, and others on local peculiarities of soil or population, and on various conditions affecting the prevalence of consumption.

The above statement makes evident the wide obligations under which the report lies for assistance in the several points investigated. Primarily to Sir R. I. Murchison, Director-General of the Geological Survey, to Professor Ramsay, Director, and to other members of the Survey. To Messrs. Whitaker and Topley thanks are due for the summary statement of the general characters of different geological formations, and for valuable aid in revising the accounts of local geology. Dr. Balfour and other officers of the army and navy medical departments, the directors of convict prisons, the superintendents of lunatic asylums, and the medical officers of hospitals have kindly given themselves labour to enable correction to be made in the registered mortality

* There are, it is true, parts of other counties where the Drift has been mapped by the Survey; but it has not been possible to regard small and divided areas with any advantage.

of districts. Among the medical practitioners who have rendered such assistance, and who can only be thanked collectively here, Dr. Greenhill, of Hastings, and Mr. Reid, of Canterbury, must be specially mentioned.

Plan of inquiry.

Fifty-eight registration districts,* being all those of the three south-eastern counties (with the exception of such as lie in the metropolitan area) have been brought under detailed examination. They were considered in two chief ways: first, as to the true consumption rate of their population, with attention to other conditions besides that of soil likely to influence this rate; and, secondly, as to the numbers of population in each district living upon various kinds of soil under various topographical conditions. The results of the two sorts of investigation were then brought together, and, as far as practicable, summary statistical conclusions have been drawn from them.

A. Consumption in districts.

THE statistical inquiry into the amount of consumption in each district was surrounded by various difficulties, which have been laboriously attacked, but have not in every instance been satisfactorily overcome. Conditions whose influence has been examined and more or less successfully allowed for are—(1) rapidly increasing population and varying rate of increase, a consideration which has required the re-calculation of many figures in the parliamentary return; (2) the inclusion of much consumption with other diseases of the lungs, which has presumably taken place in certain districts; (3) the influence of hospitals and other public institutions in increasing the mortality from consumption of the districts in which they are situated; (4) the use of particular places as resorts for consumptive invalids; (5) the special circumstances of large bodies of the male population, particularly in camps and dockyards.

In addition to making corrections and allowances of this nature it has been wished to consider other conditions influencing the local amount of consumption; such, for instance, as the urban or rural character of the population, riches or poverty; varying occupations (beyond those that have been specified); race, habits, and lodgment of people; the prevalence of intermittents; atmospherical conditions other than those due to varieties of soil. But while certain of these influences have been here and there considered, a thorough examination of them has not been possible, and their effect upon phthisis turns out, at the end of the enquiry, to be wholly thrown into the shade by the larger influence of soil.

In the following table the 58 districts are arranged in the order of their death-rate from consumption. Persons between the ages of 15 and 55 have alone been considered, and the mean of the death-rates of the two sexes is that which has primarily determined the position of districts on the table. But where the male rate was obviously subjected to disturbing influences from which the female rate was com-

* These districts, arranged upon principles that only the antiquary can by any chance comprehend, have no general relation to any natural divisions of country, and absolutely none whatever to any geological feature. The first inclination of an inquirer into the effect of geology upon disease is therefore to discard the artificial division into districts altogether, and, having mapped out several localities with broadly distinguished geological features, to investigate the amount of disease prevailing in each, by examination of the death records and other data of localities so mapped out. It is to be hoped that inquiry on this basis may yet be made, and the conclusions of this report will have done more than immediate service if they encourage to the extended observation in the future of disease in relation to geology. But for a single observer, with limited time at his disposal, the collection and analysis of disease statistics from original documents for a series of years, and for an area large enough to give valid general results, was soon seen to be impossible.

Registration Districts in the Order of their proper Mortality from Consumption.

Annual Death-rate registered from all Causes in both Sexes at all Ages.	Districts numbered according to their order.	Registered Phthisis Death Rate, 15–55.		Registered Phthisis + Lung Disease Death Rate, 15–55.		Notes, with corrections of the Phthisis columns for Hospitals, &c. Where correction is not made, it may be assumed that the registered rates are little affected by Institutions.
		Mean of Two Sexes.	Females.	Mean of Two Sexes.	Females.	
1766	3. Dartford -	261	263	325	312	(*a*) Of Elham, the male rate being of no value, 10 has been subtracted from the female rate for the approximative true mean, 313.
1620	4. Epsom - -	277	291	366	369	
2073	5. Milton - -	276	330	378	363	
1656	6. Godstone -	282	323	361	395	
2044	7. North Aylesford	289	306	383	375	(*b*) The rates of Bridge become 342 mean and 425 female, if corrected for Canterbury Hospital.
1986	9. Dover - -	296	289	368	335	
1620	10. Bromley -	294	303	348	351	
1597	11. Steyning -	295	304	363	354	(*c*) Gravesend has been classed by its female rate as being more trustworthy than the mean.
1802	12. Chertsey -	296	325	384	396	
1856	13. Croydon	303	275	385	334	
1693	15. Cranbrook -	311	381	375	446	(*d*) The rates of Eastbourne might, perhaps, be taken as slightly smaller, in consideration of some invalid visitors.
1989	16. Richmond -	313	251	407	330	
1791	17. Kingston -	315	279	423	370	
1758	18. Elham (*a*) -	277	323	344	382	
1830	19. Blean - -	315	344	381	418	(*e*) Registered male rate of Farnham being of no value, 10 has been subtracted from the female rate for the approximative true mean, 339.
1816	20. Bridge (*b*) -	331	418	399	461	
2265	21. Gravesend (*c*) -	405	331	546	435	
1732	22. East Grinstead -	333	363	402	412	
1718	24. Reigate - -	337	352	403	409	(*f*) At Battle, correction for obvious inclusion of much phthisis in registered lung disease brings phthisis rates to 344 mean and 398 female.
1666	25. Eastbourne (*d*) -	336	392	382	416	
1733	26. Farnham (*e*) -	292	349	373	405	
1701	28. Hambledon -	343	411	432	506	
1703	29. Battle (*f*) -	294	338	414	474	(*g*) For Canterbury, deduction for hospital patients brought from other districts makes true mean rate 348 and female rate 298.
2288	30. Canterbury (*g*) -	384	328	529	445	
1867	32. Hollingbourne -	352	394	417	460	
1925	33. Malling - -	356	423	423	489	
1843	34. East Ashford -	359	456	374	540	(*h*) For Farnborough, the registered male rate being of no value, 10 has been subtracted from the femal rate for the approximative true mean 371.
1781	35. Sevenoaks -	361	427	426	487	
1912	36. Guildford - -	369	379	394	433	
1426	37. Farnborough (*h*)	291	381	352	429	
1946	38. Eastry - -	371	385	445	438	
1967	39. Faversham -	370	429	449	490	(*i*) In Maidstone, deduction for deaths in lunatic asylum patients brought from other districts makes true mean rate 379 and true female rate 405.
1988	40. Rye - - -	371	438	468	501	
2265	42. Maidstone (*i*) -	434	475	546	577	

REGISTRATION DISTRICTS, &c.—*continued.*

Annual Death-rate registered from all Causes in both Sexes at all Ages.	Districts numbered according to their order.	Registered Phthisis Death Rate, 15-55.		Registered Phthisis + Lung Disease Death Rate, 15-55.		Notes, with corrections of the Phthisis columns for Hospitals, &c. Where correction is not made, it may be assumed that the registered rates are little affected by Institutions.
		Mean of Two Sexes.	Females.	Mean of Two Sexes.	Females.	
1755	43. Cuckfield - -	387	471	435	517	(*j*) At Worthing the rate should perhaps be taken as somewhat smaller, in consideration of some invalid visitors.
1733	44. Dorking - -	399	478	451	510	
1894	45. Uckfield - -	398	484	443	507	
1747	46. Hailsham - -	392	535	439	609	
1919	47. Ticehurst - -	401	457	462	503	
1790	48. Worthing (*j*) -	419	445	465	479	(*k*) In Lewes, correction for hospital and prison brings the true rate to 426 mean and 464 females.
1982	49. West Ashford -	421	542	489	612	
1947	50. Lewes (*k*) - -	502	508	575	549	
1931	51. Tenterden - -	435	528	486	579	
1765	52. Horsham - -	440	518	495	575	(*l*) The rates of Westhamptnett become 449 mean and 521 female, if corrected for Chichester Hospital.
1813	53. Westhamptnett (*l*)	441	518	490	557	
1818	54. Midhurst - -	455	539	511	597	
1824	55. Thakeham - -	454	560	497	605	
1855	56. Petworth - -	462	509	512	553	(*m*) At Chichester, deduction for hospital deaths in patients from other districts brings the rates to 536 mean and 450 female rate.
1748	57. Westbourne -	498	610	552	651	
2121	58. Chichester (*m*) -	566	463	651	539	
1934	1. Sheppey -	202	251	281	311	Population of Sheppey special and migratory; its true death-rate uncertain.
1817	2. Hastings -	498	466	588	526	At Hastings more than half phthisis deaths are invalid visitors, approximately true rates taken at half those registered.
2108	8. Thanet - -	392	364	459	415	In Thanet, deduction for visitor invalids gives as truer rates, 292 mean and 264 female phthisis.
2489	14. Hoo - - -	301	376	380	421	The population of Hoo is so small that a very few deaths more or less would entirely alter the registered rates.
2024	23. Tunbridge -	399	437	477	503	For Tunbridge, rough deduction for visitor invalids gives as truer rates, 333 mean and 364 female rate.
2310	27. Medway - -	480	353	624	440	The male rate of Medway being of no value, 10 has been subtracted from the female rate for an approximative true mean, 343; but the exact place of the district is open to several doubts.
2141	31. Romney Marsh -	348	381	429	447	Romney Marsh is affected like Hoo, and in other ways.
2200	41. Brighton - -	435	372	515	434	The true place of Brighton in the series is wholly unknown.

paratively free, the position of a district on the table has been determined by the latter rate; and where disturbing conditions have been eliminated in a district, the position given to it below is determined by the corrected, and not by the registered, rate of mortality. Eight districts, the order of which among other districts is more uncertain, have been placed by themselves at the foot of the table, with however the numbers attached to them that signify their probable position among the rest. The entire population that has furnished the materials for this table amounts to 1,118,372, living on 3,812 square miles.

B. Geology of districts.

NEXT to this examination of the amount of phthisis in each registration district, the geology of these areas has been taken up. For each district an examination has been made, as carefully as the conditions of the enquiry has permitted, into the character of the soil on which the population live. In this investigation the dip of the beds, the elevation and slope of the surface, and generally the water-holding (with some other) qualities of the ground, have been regarded as well as the geological formations that entered into the structure of the district. A prefatory account of the lithological character and usual features of the various formations has been contributed to this report by Messrs. Whitaker and Topley.

Formations comprised.

The geological formations that occur in the counties of Surrey, Kent, and Sussex* are shown in the following list:—

- Recent
  - Alluvium.
  - Blown Sand.
  - Shingle.
- Post-Tertiary
  - Brick-earth.
  - Gravel and Sand.
- Tertiary
  - Bagshot Beds
    - Upper Bagshot Sand.
    - Bracklesham Beds (Middle Bagshot).
    - Lower Bagshot Sand.
  - London Clay.
  - Lower London Tertiaries.
    - Oldhaven Beds.
    - Woolwich and Reading Beds.
    - Thanet Beds.
- Upper Cretaceous
  - Chalk
    - Chalk with flints.
    - Chalk without flints.
    - Chalk Marl.
  - Upper Greensand.
  - Gault.
- Lower Cretaceous
  - Lower Greensand
    - Folkestone Beds.
    - Sandgate Beds.
    - Hythe Beds.
    - Atherfield Clay.
  - Weald Clay.
  - Hastings Beds
    - Upper Tunbridge Wells Sand.
    - Grinstead Clay.
    - Lower Tunbridge Wells Sand.
    - Wadhurst Clay.
    - Ashdown Sand.
    - Ashburnham Beds.

* See Geological Survey, maps 1, 2, 3, 4, 5, 6, 7, 8, 9, and 11; and sections.

Alluvium. The deposit, fringing and formed by streams, consists of clay, silt, and peat, with here and there more sandy beds. By the sea there is sometimes little else than sand with sea-shells, as at Deal. It forms only tracts of marsh land, more or less subject to floods, and often below ordinary high-water mark.—*Blown Sand* consists of loose sand driven inland by the wind, and disposed in the form of irregular hillocks, constantly liable to further shifting until protected by vegetation.—*Shingle* is often banked up by the waves to some height above high-water mark, forming either a long narrow flat as at Deal, or a succession of ridges and furrows as at Romney Marsh. In the south-eastern counties the shingle consists of flint pebbles in various stages of wear. So firm and well packed is the mass of pebbles that houses are often built direct on the shingle, levelled and slightly covered with concrete.

Brick-earth here includes the loamy matter brought down by rain in districts formed by soft rocks (clay, sand, &c.); the similar deposit that sometimes caps the gravel on the terraces or gently sloping flanks of river valleys; and some of the surface beds of the Chalk district may come under the same head. Brick-earth is a mixture of clay and sand in varying proportions, but must be classed with clays rather than sands in its permeability. Like the gravel that commonly underlies it, the brick-earth of the valleys (whether on terrace or at bottom) has an even surface.—*Gravel* (and *sand*). The gravel in these counties is for the most part made up of flints from the chalk, more or less worn; and with these much sand is mixed. Tracts of gravel occur at various levels along wide valleys, and though of no great thickness they give rise to marked features in the surface of the ground, forming broad dry plains or terraces, cut through in parts by side valleys. These form outlets for the water that sinks through the gravel, and when they reach down to the beds below often have springs along their flanks.

Surface-beds of various ages on the Chalk. On the higher parts of broad chalk-tracts there is often a most irregular capping of "clay-with-flints," a brown clay crowded with unworn flints, which greatly alters the nature of the district where it occurs, forming a stiff soil, and a country which is more or less wooded instead of the open downs common with bare chalk. With this clay there is sometimes a little brick-earth.—In Kent and Surrey there are also a few patches of sand near the chalk-escarpment, the geological age of which is not certainly known. —But on none of these beds is there any noteworthy population.

Bagshot Beds. This series as a whole is permeable, being chiefly sand, and it forms in the London Basin a large tract rising to fair heights with pretty sharp slopes, not much inhabited except at Aldershot Camp. The *Upper Bagshot Sand* is a thick mass of sand which forms ridges of dry barren land, in great part capped by gravel.—The *Bracklesham Beds* are the most impervious of the series, consisting of alternations of clay, sand, and loam, about 50 feet thick in the London Basin. Here they crop out on the flanks of hills or bottoms of valleys, throwing out water from the sands above, and forming a damp soil. But at Selsea Bill they make a broad low tract much covered by gravel. —The *Lower Bagshot Sand* is light coloured, here and there clayey, passing downwards into the London clay, the junction with which is more or less wet. This division reaches a thickness of 150 feet, and rises into hills.

London Clay is a thick uniform mass of dark, tough, impermeable clay; but the few lowest and the few highest feet of it may be somewhat sandy. Where not covered by gravel, this clay forms a broad undulating tract often ending with a fairly marked escarpment that rises to a notable height, though lower and far more gently sloping than the

scarp of the Chalk. It rarely forms a plain like that of the Weald Clay. When covered by gravel, flattish plains are formed (as before stated), the drainage of which is determined by their height.

LOWER LONDON TERTIARIES. This series was once called "plastic clay," a misleading name, inasmuch as plastic clay only occurs in the middle division of it, and not always there. The broad northern tract (near London) is almost wholly of sand and pervious.—The *Oldhaven Beds* are a set of fine sand and pebble beds that occur in Kent, and stretch a few miles into Surrey. On the west the pebble beds are generally in great excess, and form dry level plains (Blackheath, Bexley Heath, Bromley, &c.), at a fair height, mostly ending off with sharp slopes, and sometimes cut through by small valleys. In East Kent, on the other hand, this series consists almost wholly of sand, and crops out on the flank or at the bottom of London Clay hills.—*Woolwich and Reading Beds.* This thin series presents perhaps more varieties of character than any other in the district under consideration. In its narrow outcrop in Surrey it consists of irregular alternations of sand and mottled plastic clay; towards the eastern part of Surrey, and in the western part of Kent, it consists of sands, loams, laminated clays with shells, and pebbly sand. In East Kent it is represented by coarsish sand. On the south of the Wealden district, sand and plastic clay again occur. These irregular beds rarely make any conspicuous feature in the form of the ground.—The *Thanet Beds* are nearly as local as the Oldhaven beds. They are found only in the north, and thin out westward near Leatherhead. In Surrey and West Kent they consist of fine loamy sand, increasing in thickness eastwards. In East Kent they get still thicker (to 80 feet or more) and also more clayey, until at last more than half consists of a sandy marl. The Thanet Beds mostly form low gentle slopes, sometimes stretching out into the Chalk district to a greater height.

CHALK. The greater part of the Chalk contains beds of flints, mostly in the form of irregular-shaped nodules, but sometimes as continuous layers. The Lower Chalk, however, is without flints, but both divisions are jointed and allow of the passage of water from the surface. The lowest part, the Chalk Marl, is more clayey than the rest, and sometimes causes springs at its outcrop. The Chalk forms a succession of hills and valleys, and ends off towards the Weald with a sharply-sloping escarpment, generally the highest ground of the district, but cut through by the rivers. The level of the Chalk-country falls, with the dip, from the escarpment, and the tops of the hills are in a gently-sloping plane: the features indeed being those of an inclined table-land cut through by valleys. From its sharp slopes and permeability chalk has a dry soil.

UPPER GREENSAND and GAULT. *Upper Greensand* is not always present, and has never any great thickness. It consists of a more or less clayey greensand with soft sandstone below: it has but a narrow outcrop and makes no great feature at the surface, forming merely a low ridge between the Chalk and Gault, or being merged in the Chalk escarpment. The junction with the Gault is apt to have springs, and the formation generally is plentifully supplied with water, though not of necessity water-logged at its outcrop.—The *Gault* is a stiff blue clay, 100 feet or more thick, also with a narrow outcrop, usually placed at the bottom of a sort of valley dividing the Chalk ridge from the slope of Lower Greensand. It is seldom much built on.

LOWER GREENSAND. On the north of the Wealden area this formation makes a broad tract of high ground, rising from the Gault and ending towards the Weald by a sharp escarpment. On the south, however, its

outcrop is narrower, and forms lower and less hilly ground.—The *Folkestone Beds* consist almost wholly of sand rising up into hills from beneath the Gault, and forming a dry country.—The *Sandgate Beds* are more clayey, consisting of loam and sandy clay, with sometimes fuller's earth. Their outcrop is generally in a slight hollow, and they often throw out water from the sand above.—The *Hythe Beds* are the most important part of the Lower Greensand in Kent and Surrey. In Kent they are known as Kentish Rag, an alternation of beds of more or less cherty limestone and soft crumbling calcareous sandstone; and in Surrey they include the calcareous sandstone known as Bargate stone. In other places the Hythe Beds consist of sand and sandstone, and they are everywhere pervious. They rise to a good height and end off towards the Weald with a sharp escarpment.—The *Atherfield Clay* is the lowest member of the Lower Greensand, but as it is merely a few feet of stiff clay, it has been taken with the Weald Clay for the purposes of the present inquiry.

Weald Clay. This is a great mass of clay and shale, 600 feet thick, with occasional thin layers of shelly limestone, calcareous sandstone, and ironstone. In the neighbourhood of Horsham there is a thicker but local bed of sandstone and calcareous grit alternating with clay, in all about 10 feet thick. The lowest part of the Weald Clay is often sandy. This formation does not reach any great height except where it rises up to the sharp escarpment of the Lower Greensand, or where outliers of it occur on the high tracts of the Hastings Beds; but it forms a broad flattish vale, with only a few low hills, and it has often cappings of gravel along the streams that wander through it.

The Hastings Beds consist of alternations of sand and clay, the former predominating, so much so that the whole series has been termed "Hastings Sand." * They rise from below the Weald Clay flat, and form undulating ground. The lower beds occur mostly towards the middle of the Wealden area, and form high land, their dip being greater than the slope of the ground; but they are frequently brought up by faults and folds in other places. This mode of occurrence renders it difficult to describe the features of the districts, except in very general terms.—The *Tunbridge Wells Sand* consists, on the east, of a mass of fine sand and soft sandstone, with thin beds of loam and clay, and altogether is about 150 feet thick. On the west it is divided into two parts by a local bed of stiff (Grinstead) clay, the thickness of the Upper Sand being about 100 feet, of the Grinstead Clay up to 60 feet, and of the Lower Sand about 60 feet.—The *Wadhurst Clay* is a stiff clay or shale, with sometimes a little stone, and is seldom less than 100 feet in thickness.—The *Ashdown Sand* is like the Tunbridge Wells Sand, but is nowhere divided by any thick mass of clay.—The *Ashburnham Beds* do not crop out to the surface over any large area. They consist near Hastings of mottled clays, with layers of sandstone; but near Battle and Brightling of clays, shales, and sandstones, with many beds of limestone. As a whole, they form a rather retentive soil, but much less so than Weald Clay or Wadhurst Clay.

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* F. Drew. "On the succession of beds in the 'Hastings Sand.'" *Quart. Journ. Geol. Soc.*, vol. xvii., p. 271 (1861). P. 285. "Of the sandy beds there is "more to be said. The sand itself is nearly always extremely fine, almost an im- "palpable sand. On this account it bears itself somewhat in the same way that "clay does as regards the presence of water; instead of absorbing it like an ordinary "sand, it becomes a pasty mass that can be moulded like a very light clay, and this "though it contains no alumina." P. 286. "Loam occurs in large quantities in the "sandy beds."

THE 58 registration districts of the south-eastern counties are described below in the order in which they appear on the table (page 97) which shows their relative death-rates from consumption. For each district is shown (1) the acreage and population; (2) the general geological and topographical features; (3) the character of the formations and soils upon which its chief towns and villages are placed; (4) the numbers, as nearly as can be judged, of the residents upon each description of soil; then the registered phthisis rate for males and for females is given, and the account ends by stating any circumstances that may cause the true rate to differ from that which is registered, and by making such allowance for these as is possible.*

Geology and consumption of districts in order of previous table.

[3.] DARTFORD, Kent. Acres, 53,109. Population, 32,316. Maps 1 and 6.

Dartford.

Is geologically in two portions, the southern of Chalk with surface clay, sloping downwards from south to north; the northern is the main of Tertiary Beds, consisting on the west of a mass of Lower London Tertiaries, with a little London Clay, and on the east of outliers of the same over chalk. Over both portions of this northern district there are deposits of brick-earth and drift gravel. The north-western or Tertiary district consist of London Clay, scarcely at all inhabited; a broad tract of sandy pebble-beds, with Woolwich and Thanet Beds below them. The pebble-beds, on which great part of the population lives, have a level surface cut through by valleys, and are mostly pervious, and vary from 10–50 feet in thickness. The beds below are somewhat less pervious, but are only impervious where the clay shell-beds of the Woolwich series occur, and they crop out upon slopes. Very few people live upon impervious soil. The whole district is divided by the valley of the Darent, and on the north-west it is also cut into by the valley of the Cray. The marshes bordering the Thames are uninhabited.

Dartford lies in the valley of the Darent and on the slopes of the valley. About a third of the town is on alluvium, flat and at low level, and it must be wet. The rest is on gravel over chalk, and on bare chalk, at a higher level and quite dry.

A great number of the villages of this district are situated along the Darent valley. Of these *Wilmington* is on thin beds of gravel, brick-earth, and Thanet Sands overlying chalk, on a rise and in a dry situation. *Sutton Darent*, *Eynesford*, *Horton Kirby*, and *Farningham* are on local gravels and on chalk, bordering the river; parts of them may have wet soil, but in the main lie so as to be quite dry. *Crayford*, *Erith*, and *Bexley*, with parts around them, stand on various gravels and sands, and upon chalk. Portions of them are rather low but upon dry slopes. Parts of *Bexley* and *Crayford*, however, are on alluvium. Besides outlying villages on bare chalk, *Swanscombe*, *Southfleet*, and other places

* The number in brackets prefixed to the name of each district indicates the position in which the district stands among the 58 districts examined, in respect of its phthisis death-rate. Table, p. 59. The map references are to the one-inch maps of the Geological Survey, which bear the same numbers as the Ordnance maps of the same scale. Population, unless where otherwise stated, is that of the census of 1861.—The names of places here signify the town or village that is commonly so known, and not the parish of the name, which often stretches far away, and includes other places, or else does not include the whole of the town. Minute details of each whole parish were of course taken into consideration in forming the numerical statement subjoined to each district. The phthisis rate shows the male and female deaths annually (1851-61) occurring between the ages of 15–55, per 100,000 males and per 100,000 females living at that age in each district.

are on Tertiary outliers (Thanet Sands and drift gravels); at Swanscombe there is clay. Greenhithe and Stone lie on chalk, bordering the Thames, not many feet above high-water mark. Several places of less size are on the pebble-beds and other parts of the Lower London Tertiaries.

Approximate number of population resident on alluvium, 2,700; on uncovered London Clay, 100; on Lower London Tertiaries, 13,580; on Chalk, 15,483; and on board vessels, 453.

Phthisis death-rate for males	-	260
„ „ females	-	263.

[4.] Epsom, Surrey. Acres, 41,180. Population, 22,409. Map 8.

Epsom.

The northern half of this district consists of Tertiaries and the southern half of Chalk, the towns and villages being mainly at the junction of the two formations.

In a line across the district, *Great* and *Little Bookham*, *Fetcham*, *Leatherhead*, *Ashtead*, *Epsom*, *Ewell*, *Cheam*, *Sutton*, and *Carshalton* are situated on this junction of the tertiaries with the chalk, the position having evidently been chosen for facility of procuring water. The inhabited parts of these places range from the London Clay across the Woolwich and Reading Beds and some Thanet Sand to the chalk. Some have patches of gravel over the other formations. The chalk near these towns and villages rises to the south with a fair slope, and must be pretty full of water near its junction with the tertiaries.

The surface slope of the tertiaries northward from their junction with the chalk is sometimes upwards, sometimes downwards, the latter chiefly where the country is intersected by valleys. But the dip of the beds is northerly, so that, in so far as they are pervious and not below the level of the waterline in the chalk, water can get away by them. But these tertiary beds are mostly impervious for some part of their thickness, and the level of saturation would (in the absence of side valleys) soon be reached below the surface.

Whether the soil is damp or dry depends upon minute local circumstances that affect the saturation level. This ranges probably from a very few feet to 50 or thereabouts. At Epsom, before drainage works, there were places where water overflowed the surface on a well being dug; there are of late years few places that have water so near the surface as 5–6 feet.

On the west this district is drained by the Mole, on the east by the Wandle, and between these rivers by the Hogs-mill and another stream.

Cobham and *Stoke D'Abernon* are on gravel underlain by London clay and surrounded by alluvium. *Banstead* is on an outlier of Thanet Sand (with irregular deposits of clay) over the chalk.

Approximate number of residents on London Clay with gravel, 2,409, without gravel, 3,000; on Lower London Tertiaries, 8,500, some of whom live on impervious beds; and on Chalk, 8,500.

Phthisis death-rate for males	-	264
„ „ females	-	291.

[5.] Milton, Kent. Acres, 35,409. Population, 14,775. Maps 3 and 6.

Milton.

This district has a general slope downwards from south to north, with valleys and ridges running more or less in the same direction. The road from Chatham to Canterbury through the district gives a good notion of the varieties of level. This ranges from 140 feet about Rainham to 99 at Newington, then rises to 170 feet, and near Milton is

only 54 feet; at Sittingbourne 35, and at the eastern edge of the district 10 feet higher. About a third of the district is Chalk, a third London Clay and Lower London Tertiaries, with gravels and brick-earth, and the remaining third (roughly speaking), on which there is very little population, is alluvium.

Sittingbourne and the adjacent *Milton* with other villages are placed at the junction of the Tertiaries with the chalk on a moderate slope, and with more or less brick-earth. Parts of Milton are on alluvium. *Rainham* is on chalk with patches of Thanet Sand and, perhaps, some brick-earth. Bordon and many other villages are placed on the chalk, or on Tertiary outliers over it. The lower beds of the Thanet Sand which form these outliers are less pervious than the bulk of that formation. Newington and Hartlip are on Tertiary Sands; the former in a valley, yet at a fairly high level, and with good slope. Except *Little Halstow* and a few small places, which are situated on patches of gravel or sand, there is no population on the marsh area of the district.

Approximate number of residents upon alluvium, 500; gravel on London Clay, 270; uncovered London Clay, 760; Lower London Tertiaries, 7,480; chalk, 5,765.

Phthisis death-rate for males - - 222
" " females - - 330.

Ague is rather common in this district, especially about the Swale. There is some at Sittingbourne.

[6.] GODSTONE, Surrey. Acres, 43,848. Population, 9,642.
Maps 6 and 8.

Godstone.

The northern part of the district is Chalk; then follows a central band of Upper Greensand, Gault, and Lower Greensand, and to the south is a broad tract of Weald Clay, with a very small bit of Hastings Beds. Except the Weald portion, the district is undulating and fairly high.

Godstone, *Bletchingley*, *Lympsfield*, and *Oxted* are the largest places, but none of them are more than villages. They are all on the Lower Greensand, and a sandy part of it; the two former having a band of more loamy sand cropping out below the town. The slope of the ground and the dip of the beds, however, is such as to allow of water getting readily out of the soil beneath these places. All these villages are on good slopes at fair altitudes.

Caterham, *Warlingham*, *Chelsham* and some smaller places are on chalk; they mostly lie high where the chalk is capped by gravels and brick-earth, but some parts are in valleys of the chalk; only farms and scattered hamlets occur on the Weald Clay.

Approximate number of residents on Chalk, 2,242; on Upper Greensand, 60; on Gault, 50; on Lower Greensand, 5,670; on Weald Clay with some gravel, 500; on the same without any gravel, 1,050; and on Hastings Beds, 70.

Phthisis death-rate for males - - - 241
" " females - - - 323.

Note the small population, causing rates to be affected by numerically few cases of phthisis.

[7.] NORTH AYLESFORD, Kent. Acres, 41,732. Population, 19,121.
Maps 1 and 6.

North Aylesford.

A Chalk district in the main, the Chalk forming a slight trough from east to west across its area, with the highest ground at the south. Beds of the Lower London Tertiaries, chiefly pervious, cross the

district in the same direction, and there is a small uninhabited piece of London Clay.

Northfleet and *Strood* are the largest places. The former lies 80 or 100 feet above the Thames, on Chalk covered by brick-earth and gravel; adjacent parts are on Thanet Sands. *Strood* with *Frindsbury* are on the same formations, great part lying low near the level of the Medway, but other parts of them being on rapidly rising ground. Some houses of Strood are on alluvium; parts of Frindsbury on Thanet; Meopham with smaller villages stands on Chalk. *Shorne* and *Cobham* are on sandy tertiaries over Chalk, on a good slope. *Lower Halling* is at a lower level near a marsh, on gravel over Chalk. *Cliffe* is on bare Chalk, sharply scarped towards the river.

Approximate number of residents on alluvium, 276; on Lower London Tertiaries, 3,500; on Chalk, 15,345.

Phthisis death-rate for males	-	-	273
„ „ females	-	-	306.

[9.] Dover, Kent. Acres, 29,881. Population, 31,575. Map 3.

Dover.

A high Chalk district cut through by the valley of the Dour.

Dover itself is largely built upon shingle and estuary alluvium, the higher parts upon a coarse rubble of fragments of chalk and flints. The Castle, the Citadel Barracks, and some houses of the town are upon bare chalk. *Charlton*, *Buckland*, and *River* are in the valley, on sharp slopes, on chalk or similar rubble to that of Dover. Charlton is slightly on alluvium. Other villages are on dry Chalk, generally lying high.

Estimated number of residents on alluvium, 1,791; on shingle, 8,000; on Chalk, 21,534; on vessels, 250.

Phthisis death-rate (registered) for males		-	303
„ „ females		-	289.

The occupation of many males being very special, and the true mean number of males being uncertain, the published male rate appears to be of inferior value. But as corrections made on these two grounds would probably be in different directions, with a tendency to put the male rate higher, it is thought better to adhere to the mean of registered rates in assigning Dover its place in the series of districts, rather than to deduce a new mean from the lower female rate.

[10.] Bromley, Kent. Acres, 39,927. Population, 20,368. Maps 1 and 6.

Bromley.

The southern part is of chalk with local cappings of surface clay; the ground slopes downwards from south to north, following the dip. The northern portion is a Tertiary country, rising from the chalk by a sharp escarpment about the middle of the district, and sloping downwards to the north. This consists of outliers of London Clay, on a broad tract of pebble beds underlain by sands and clays. The eastern part of the district is intersected by the valley of the Cray.

The largest places are *Bromley*, *Beckenham*, and *Chislehurst*, mainly on pebble beds and sands. Very small portions of these places are on the more retentive Woolwich Beds and London Clay. Some smaller places are similarly situated. From their elevation and the slope of their beds they must be dry. Along the Cray Valley are the four villages of the *Crays* and *Orpington*, seated indifferently on alluvium, gravel, Thanet Sand, and Chalk. Almost all the houses are on pervious

strata, bordering streams on slightly sloping ground, but lying rather low. *Farnborough* and *Keston* are high up on the slope of the Tertiary escarpment. *Cudham*, *Chesterfield*, *Knockholt*, *Down*, and other places are on Chalk.

The road from Bromley through the centre of the district towards Sevenoaks gives a fair notion of the slopes of the district. These are numerous and varied, the extremes of height being 350 and 210.

Estimated number of population living on alluvium, 368; on uncovered London Clay, 1,000; on Lower London Tertiaries, 15,500; and on Chalk, 3,500.

Phthisis death-rate for males	-	285
„ „ females	-	303.

These death-rates are somewhat lower than they should be, through the method adopted in the published return of taking the arithmetical mean of two censuses, instead of the true mean number of a rapidly increasing population.

[11.] Steyning, Sussex. Acres, 44,344. Population, 24,053. Map 9.

Steyning.

Geologically is in two parts; a northern smaller part of Weald Clay, Lower Greensand, Gault, and Upper Greensand, and a southern larger part of Chalk. Both parts are intersected by the valley of the Adur. The Weald Clay and the Gault are wet and low, the other formations mainly high and dry.

Hove, a suburb of Brighton, is the largest place, situated on a flat of chalk, partly covered by gravel or chalky rubble, with a little brick-earth. The elevation of the church is 44 feet above the mid-level of the sea, and there is no water within 20–30 feet of the surface. *Shoreham* is next in size. It lies low, and, with *New Shoreham*, *Southwick*, and other villages, on chalk, bordering the sea or near a river, and capped by alluvium or a few feet of brick-earth on the chalk. *New Shoreham* lies flat, at about high-water mark. *Steyning* is at the foot of the Chalk hills, near the junction of the Chalk and Lower Greensand. Its soil is dry, water not coming nearer to the surface than 19–20 feet. *Henfield* and smaller villages are on Lower Greensand. Henfield is partly on the clayey (Sandgate) beds. A few small places lie on the Weald Clay, at its junction with the Lower Greensand. The ground is everywhere undulating, and the Chalk rises to hills of considerable height.

Estimated number of residents on alluvium, 120; on Chalk, 18,993; on Upper Greensand, 1,560; on gault, 53; on Lower Greensand, 1,920; on Weald Clay (without gravel), 1,030; and 377 persons were on board vessels.

Phthisis death-rate for males	-	287
„ „ females	-	304.

[12.] Chertsey, Surrey. Acres, 43,541. Population, 18,642. Map 8, and Section No. 74.

Chertsey.

In the main this district consists of Bagshot Beds, with gravel and alluvium at the lower levels; the middle and lower members of the Bagshot series are most represented, the middle being more or less clayey, the lower nearly pure sand.

Chertsey (with *Addlestone*) and *Walton* (with *Hersham*) are the largest places. These, with *Weybridge* and *Byfleet*, are on thick beds of gravel, for the most part underlain by Bagshot Sands, but at Walton

and Hersham by London Clay. Except Chertsey and Byfleet these villages are on fair elevations, but the latter places lie low near streams, and near Chertsey the land is liable to be flooded. *Chobham* is a largish village on gravel, lying low, near a stream. *Bagshot* and *Windlesham* lie on a slope of the middle Bagshot Beds.

Approximate number of residents on alluvium, 400; on gravel over London Clay, 5,400; on Bagshot Beds, 12,842; of which 2,400 may be taken as on the less pervious Bracklesham Beds.

Phthisis death-rate for males	-	268
„ „ females	-	325.

[13.] Croydon, Surrey. Acres, 32,803. Population, 46,474. Maps 6 and 8.

Croydon.

Of this district the town of Croydon forms so large a proportion that its rate must largely govern that of the whole. It stands at the junction of the Chalk and Tertiaries, where that line is cut through by the valley of the Wandle. Over the Thanet Sands, Woolwich Beds, and London Clay there is a thickish covering of gravel (15 feet or so) in many parts of the town. The Wandle is here a nailbourne, and rises at various points along the valley according to the wetness of the year. The works that have been undertaken for the sanitary improvement of Croydon were in the main completed in 1853, or at the early part of the period to which the subjoined phthisis rates refer. Before their execution the lower parts of the town were very wet, as might be inferred from geological considerations, and the roads were charged with water in wet weather. The drainage works of 1850–53 consisted, *inter alia*, in the removal of a milldam, the construction of a culvert to take off the water of the chalk in wet seasons, and the pumping of much water from deep wells. A notable influence was produced on the water of the soil, and it is shown in the Report of last year (page 102) that, simultaneously with this change, a considerable reduction of the amount of consumption was effected.

Mitcham is on gravel over London Clay, on a slight slope bordering the Wandle. *Penge* and *Upper Norwood* are on London Clay, without gravel; the former stands somewhat low but on sloping ground, the latter at a high level. There are scattered villages situated either on the pebble beds and sands of the Tertiaries or on the Chalk, in either case having good natural drainage.

Approximate number of residents on alluvium, 474; on gravel over London Clay, 16,000; on London Clay without gravel, 11,600; on Lower London Tertiaries, 9,800; and on Chalk, 8,600.

Phthisis death-rate for males	-	331
„ „ females	-	275.

Besides the consideration above stated, observe that Croydon town and some other parts of the district are much used as a residence by well-to-do Londoners; and consider further, that in the case of a rapidly increasing population, the method by which the published rates are computed, viz., on the arithmetical mean population between two censuses—by making the population larger than the true mean of 10 years—makes the published rates unduly small.

[15.] Cranbrook, Kent. Acres, 40,249. Population, 13,412. Maps 5 and 6.

Cranbrook.

A district of the Hastings Beds, consisting of hills and valleys of Tunbridge Wells Sands and Wadhurst Clay, with a small patch of

Weald Clay at the north-east. In several places, in valleys and along faults, Ashdown Sand comes to the surface. The area may be considered as two-thirds sand and one-third clay. It rises to a moderate elevation: from 200 to 400 feet above the sea level.

Cranbrook itself is on a rise of Tunbridge Wells Sand above Wadhurst Clay, with good natural drainage. *Goudhurst* is on much the same formations, but is placed on a sharper slope and on higher ground. *Hawkhurst* and various villages on the south of the district lie just on the junction of the same sand and clay, evidently having been placed here for facility of obtaining water. *Benenden* is on the Wadhurst Clay; *Frittenden* on Weald Clay.

Of the residents in this district 100 are estimated to live on Weald Clay with gravel, 800 on Weald Clay without gravel, 1,200 on the clays of the Hastings series, and 11,312 on its sandy beds.

Phthisis death-rate for males	-	242
„ „ females	-	381.

[16.] Richmond, Surrey. Acres, 4,339. Population 18,802. Map 7.

Richmond

This district is bounded on the north and west by the Thames, and consists wholly of London Clay, in great part covered by gravel and sand, but with very little alluvium. The gravel makes a broad flat along the Thames, except at the southern part of Richmond, where the London Clay is touched by the river, and forms a steeper bank for half a mile. There are also flat caps of gravel on the clay hills of Richmond Park. The London Clay rises up from beneath the gravel southwards and eastwards.

Richmond is placed at the edge of the low-level gravel, and partly on the rising ground of London Clay on the south. *Petersham*, *Kew*, *Mortlake*, and *Barnes* are on the gravel.

Twelve hundred people are estimated to live on London Clay without gravel, and the remaining 17,602 of this district upon gravel over London Clay.

Phthisis death-rate for males	-	375
„ „ females	-	251.

[17.] Kingston, Surrey. Acres, 22,487. Population, 36,479. Maps 7 and 8.

Kingston.

A district almost wholly of London Clay covered by gravel, along the Thames. Esher alone is on a patch of Bagshot Sand.

The greater part of *Kingston* is on gravel over London Clay, the surface of the ground sloping slightly (but that of the clay rather more) towards the river. Some newer parts of the town are on a slope of the clay. Probably the waterline in the gravel is about 10–15 feet from the surface. *Thames Ditton* and *East and West Molesey* are similarly placed on gravels over clay, but without the rising ground of clay behind. *Wimbledon*, *Long Ditton*, and *Malden* are almost wholly on gravels over London Clay.

Approximate number of residents on Bagshot Beds (all pervious), 1,460; on London Clay with gravels, 28,839; on the same without gravels, 6,200.

Phthisis death-rate for males	-	352
„ „ females	-	279.

Kingston may be taken as an illustration of the error arising from the method in which the death-rates of Parliamentary return No. 12 have been computed. The rates have been taken on the arithmetical mean of the population at the two censuses, 1851 and 1861. This is larger than the true mean number of people living in the district between the two censuses. The death-rates consequently come out smaller than the true death-rates. In Kingston district the death-rate of females, 15–55, from phthisis is given (Parliamentary return) at the above figures, 279. Computed upon the more correct mean number of females at that age, with the assumption that the rate of increase was uniform between 1851 and 1861, the death-rate in females was 287 ; or computed on the data of the three censuses 1841–51–61, which show that the rate of increase was itself rapidly increasing, the truest death-rate that can be got for females aged 15–55 turns out to be 293.

Now Kingston, especially in its female rate of increase, is an extreme example among the districts under consideration, of a district altering its population otherwise than by the natural methods of increase. This being so, and the extent of error being at the most only between 279 and 293, the death-rates given for other districts in the Parliamentary return may be taken as seldom varying very seriously, by reason of population fallacies, from the true rates.

[18.] ELHAM, Kent. Acres, 43,197. Population, 26,925.
Maps 3 and 4.

Elham.

The northern two-thirds are mostly high, and consist of Chalk with irregular patches of surface clay and a little sand, but this part is thinly populated. The southern third is at a considerable height, and consists of Gault with Lower Greensand (the Upper Greensand being here insignificant), with Weald Clay at the extreme south, at Hythe ; hereabouts, too, a small part of the district is on marsh.

Folkestone is the chief town. The eastern and north-eastern parts of it (which only lately have been much built on) are on gault, on a gentle slope. The main part is on the upper division of the Lower Greensand, which here consists of sand with irregular layers of sandstone, the "Folkestone Beds." The levels of the town range from 66–118 above mid-level of the sea. East Cliff and West Cliff have both good slopes to the valley, and the soil must everywhere be very dry, except perhaps in a few small places where brick-earth and gravel occupy the valley.

Hythe is at the foot of the escarpment of Lower Greensand, where the Atherfield and Weald Clays are covered by masses of the pervious strata fallen from above. Its southern part is on shingle. The ground on which the town stands slopes downwards pretty rapidly from north to south. Above the town, on the north, the pervious Lower Greensand stands in cliffs. On the east and west of the town, however, there are deep valleys in which the waters of the Greensand are thrown out by the Atherfield Clay, and this bed lies not far below the surface, in the principal part of Hythe. There are many springs at and just above the town. *Sandgate* is mostly on the loamy beds of the middle division of the Lower Greensand facing the sea, some 10 feet above high-water mark. *Elham* and *Lyminge* are on a strip of gravel in a chalk valley, the latter place at a watershed ; and they are dry enough. Other villages on the chalk are on spots where thin caps of clay or gravel exist, at high levels and dry. The camp at Shorncliffe, with 4,204 military in 1861 (none in 1851), is on the Folkestone Beds before mentioned, on a well-drained soil.

Of the population of Elham district, it is estimated that 370 live on alluvium, 3,975 on Chalk, 2,660 on Gault, 17,420 on Lower Greensand, and 2,500 upon Weald Clay.

Phthisis death-rate for males - - -	232
„ „ females - -	323.

Note the soldiers as a probable disturbing element of the male rate.

[19.] BLEAN, Kent. Acres, 32,221. Population, 16,161. Map 3.

Blean.

A Tertiary district. The divisions of the Lower London series crop out along a line roughly parallel to the channels of the Stour and Wantsome on the south and east. To the north and west of this line London Clay forms a hilly wooded country, with drift gravel on its higher parts. Along the Stour there is in many places a slope of gravel and brick-earth, and a flat of alluvium.

A north-west *suburb of Canterbury* reaches into this district. It is on a slope (120 to 60 feet) of brick-earth over Thanet Beds and chalk. *Whitstable* is on shingle and alluvium, lying low, nearly on the sea level. The town of *Herne Bay* is on almost a flat of London Clay, 20–30 feet above the sea. *Herne* itself is on an inlying patch of the sands below this clay. *Sturry* lies on a flat of gravel just above the Stour (15–16 feet above mid-level of the sea), where the river ceases to be tidal; it must be water-logged. *Blean* village stands on a slope of London Clay, where it is thinly capped by gravel. Other places are on the Lower London Tertiaries or at the edge of the London Clay, and do not appear to be wet.

Approximate number of people living on alluvium, 2,100; on shingle, 700; on London Clay, gravelled, 950; without gravel, 5,800; on Lower London Tertiaries, 6,611.

Phthisis death-rate for males - - -	286
„ „ females - - -	344.

A small addition to these rates should be made for patients of Blean dying in the Kent and Canterbury Hospital, but the amount of this correction is inconsiderable.

[20.] BRIDGE, Kent. Acres, 41,394. Population, 11,316. Map 3.

Bridge.

Consists of a northern part of sandy Tertiaries and a southern part of Chalk, the former lying somewhat low and sloping towards marsh, at the edge of the Stour, the latter consisting of high downs with valleys, in some of which intermittent streams (known as nailbournes) occur.

Along the valley of the Little Stour, which is often dry in a great part of its course, there are eight or ten villages on Chalk or valley gravel, evidently placed here for the sake of water. Other villages are on the high Chalk country. *Chartham* and some other places on the Great Stour are very probably kept wet by the milldams in the river at Canterbury. *Fordwich* and *Stodmarsh* are near the same river, where it is tidal below Canterbury, on low lying tertiary sands and valley gravel.

Number of residents estimated to live on alluvium, 400; on uncovered London Clay, 50; on Lower London Tertiaries, 3,680; and on Chalk, 7,186.

Phthisis death-rate for males - - -	244
„ „ females - - -	418.

In 1851–60, seven males and two females from Bridge died in the Canterbury Hospital of phthisis, being between the ages of 15 and 55.

This [illegible] he largest number of deaths from any outlying district occurring there, an [illegible] correction has therefore been made for them. This is a good illustration of the degree of disturbing influence likely to arise from the presence of a county hospital in an adjoining district. The corrected rates are—males, 259 ; females, 425 ; and the difference from the registered rate is therefore of no material amount.

[21.] GRAVESEND, Kent. Acres, 1,541. Population, 18,782. Map 1.

A small district, comprising *Gravesend* and *Milton-next-Gravesend*, which form a single town only. It consists of a Tertiary outlier of the Thanet, Woolwich, and Oldhaven Beds, upon Chalk. Upon the slope of this outlier, and on Chalk between it and the Thames, the town of Gravesend is built, the greater part being on Chalk and Thanet Sand. The only impervious portions in th[illegible] re clays in the Woolwich Beds and clayey parts at the b[illegible] Thanet Sand. In view of these, and of the slightly troug[illegible] the base of such outliers as these, there is a likelihood of su[illegible] of the town being here and there damp. Near the edge of [illegible] ver, too, the foundations of the houses are near the water-line of the chalk ; but the great bulk of the people live on quite porous and sufficiently sloping dry soil.

Estimated number of people resident on alluvium, 50 ; on Lower London Tertiaries, 4,000 ; and 13,989 on Chalk ; and 743 on board vessels.

Phthisis death-rate for	males	-	479
„ „	females	-	331.

Observe the very disproportionate male death-rate, of which the only explanation that can be suggested is, that Gravesend is not a little used by the poor of the east end of London, who, when they get consumptive, find this town cheap, and to their notions like the sea-side. This use of the town would probably be more by males than females.—Ague is on the decrease in Gravesend, except in so far as it is imported from Essex. On the dispensary books 61 cases of intermittents appeared in 1856, 371 in 1859, and 235 in 1860.

[22.] EAST GRINSTEAD, Sussex and Surrey (*Lingfield*). Acres, 61,317. Population, 14,097. Maps 5, 6, 8, 9.

East Grinstead. A wholly rural district, on the various sands and clays that make up the Hastings Beds of the Wealden series. Very small part of Weald Clay; more than three-quarters of the area are sand. There must be considerable variety of natural drainage here, but for the most part it is good, the beds as well as the contour of the country having a fair slope. Crowborough Beacon, the highest point in the Wealden country (800 feet), is at the south-east edge of this district, on the boundary of Uckfield.

The largest place is *East Grinstead* itself ; a long street in the course of which are found alternations of sands and clays, known as the Upper Tunbridge Wells Sand, the Grinstead Clay, the Lower Tunbridge Wells Sand, and the Wadhurst Clay. Most of the town is on a slight rise of the Lower Tunbridge Wells Sand, the clay beneath sloping away so that the sands cannot be water-logged. *Hartfield*, *Withyham*, and *Forest Row* are on the Ashdown Sand, near the bottom of a valley, where the ground slopes towards a stream. *Crawley*, at the north-western corner of the district, is on Weald Clay, flat and moist. Part of *Lingfield* is on Weald Clay, part on Hastings Beds.

Approximate number of population living on Weald Clay (without gravel), 1,650 ; on the sands of the Hastings Beds, 11,547 ; on the clays of the same, 900.

Phthisis death-rate for males	-	-	- 303
„ „ females	-	-	- 363.

[24.] REIGATE, Surrey. Acres, 51,276. Population, 20,109. Map 8.

Reigate.

The northern quarter of this district is Chalk with local cappings of surface clay and loam, and some outliers of Thanet Sand. Then across the district, from east to west, run narrow bands of Upper Greensand and Gault, with a broader band of Lower Greensand. The southern two-thirds of the district is Weald Clay, in great part capped with gravel, particularly along the streams. This clay is not altogether flat ; the London and Brighton railway passes through some six miles of it, in which are elevations of 210, 250, 180, 210, 150, and 185 feet—a good deal of variety for a Weald Clay district.

Reigate and *Redhill* are placed on the edge of the Gault and on Lower Greensand; they are mainly on the upper more sandy division of the Greensand, the middle more clayey division cropping out south of the town. Their natural drainage must be good and their soil dry. Besides other places on the Lower Greensand, *Betchworth* is on the lowest sandy and stony beds of this formation, where it is capped by some gravel; the western part of Betchworth, however, lies low and flat, nearly upon Weald Clay.

Headley and *Walton-on-the-Hill* are on sand outliers over chalk. Upon the remainder of the chalk area are scattered villages and hamlets. *Gatton* and *Merstham* are on Upper Greensand ; a part of the latter stretches down to the Gault, but on Gault itself there is scarcely any population. On the Weald district are many small villages and farms, most of them being placed on the thin irregular beds of gravel which overlie the clay.

Estimated number of residents on London Clay (uncovered), 50; on Lower London Tertiaries, 350 ; on Chalk, 1,480; on Upper Greensand, 1,020 ; on Gault, 240 ; on Lower Greensand, 10,580 (of whom 1,000 may be taken to be on the Sandgate Beds); on Weald Clay with gravel, 4,389 ; on the same without gravel, 2,000.

Phthisis death-rate for males	-	-	- 322
„ „ females	-	-	- 352.

[25.] EASTBOURNE, Sussex. Acres, 38,072. Population, 10,721. Map 5.

Eastbourne.

A coast district. The southern half is bare chalk and high ground. The north-eastern half slopes from the Chalk downwards, over Upper Greensand, Gault, Lower Greensand, Weald Clay, and Tunbridge Wells Sand, to the Pevensey Level, marsh and Weald Clay.

Eastbourne village is at an elevation ranging from 89 to 21 feet, on the edge of the Chalk, and the new town stretches over the Upper Greensand. Below this is the impervious Gault clay, the slope of which however is such as not to affect the natural drainage of the houses that lie on the pervious beds above. *Seaford* is on Tertiary Sand over Chalk, on a river at the edge of the sea, and must also have good natural drainage. *Pevensey* and *Westham* are low-lying places (21 to 10 feet), at the edge of the marsh land. Several small villages lie either at the junction of the Chalk and Upper Greensand, or else on the chalk, at various levels. *East Dean* has 144 feet of altitude. *West Dean*,

Lullington, and *Alfriston*, being in valleys, may have the subsoil water near the surface.

Approximate number of residents on alluvium, 60; on shingle, 200; on Lower London Tertiaries, 1,000; on Chalk, 5,071; on Upper Greensand, 3,160; on Lower Greensand, 50; on Weald Clay without gravel, 100; and on sand of the Hastings Beds, 1,080.

Phthisis death-rate for males	-	-	280
„ „ females	-	-	392.

Possibly these rates might be a trifle lower if deduction were made for visitor invalids dying at Eastbourne.

[26.] FARNHAM, Surrey. Maps 8 and 9. Acres, 31,197. Population, 30,707; having increased from 11,743 in 1851, mainly by reason of the establishment of Aldershot Camp.

It is a long straggling district. Tertiary and secondary formations are represented in it from the Bagshot Beds at the north, to the Lower Greensand at the south. The Bagshot Beds form high ground, the less pervious members of the series (Bracklesham) being on the slope of the hill, which has sands (Upper Bagshot) and more or less drift gravel at the top. The London Clay then (with various undulations) slopes downwards to the valley of the Blackwater, where clayey Reading Beds form a narrow flat tract, which is however uninhabited. Then the chalk rises in a gentle hill, on the other side of which the lower ground —the valley of the Wey and a branch of it—is formed by Gault, cropping out with considerable dip. From hence the Lower Greensand rises to a considerable elevation.

Aldershot South Camp, and the towns that are creations thereof, are on a fair elevation and slope, on the upper and middle divisions of the Bagshot Beds, bordering the Blackwater. Parts of the village of Aldershot extend on to London Clay. *Frimley* stands on gravel, and a small part on alluvium. The town of *Farnham* is chiefly on gravel over Gault, small parts being on alluvium, on Chalk, and on gravel over Lower Greensand. *Wrecklesham* is somewhat similiarly circumstanced. Artificial drainage would certainly be required to keep such a soil as this from being wet over a great portion, and this has not been supplied upon any considerable scale. There are outlying villages on the Lower Greensand; the chief of them, *Frensham*, is in the valley.

Approximate number of residents on alluvium, 300; on Bagshot Beds, 20,457 [an unknown portion of whom (in Aldershot Camp) are on the Bracklesham division]; on uncovered London Clay, 3,220; on Chalk, 200; on Upper Greensand, 50, Gault, 2,680, and Lower Greensand, 3,800; all of which last may be taken as sandy.

Phthisis death-rate for males	-	-	236
„ „ females	-	-	349.

Note that the military hospital for the whole of Aldershot Camp (including the northern part in Farnborough district) is situated here. The male rate cannot be corrected, and as it stands is of no value. The female rate is probably subject to certain minor disturbing influences, but their effect cannot be estimated.

[28.] HAMBLEDON, Surrey. Acres, 60,351. Population, 13,907. Maps 8 and 9.

Hambledon.

The northern and western boundaries of the district project into a Lower Greensand country, where sand and calcareous sandstone form high ground that slopes to the north, and has excellent drainage. This

part, though of small area, has nearly half the population. The remainder is a tract of Weald Clay, with a patch of valley gravel; the population here is in scattered hamlets. The Section of the Geological Survey, No. 73, running northward from Haslemere across the Hog's Back into part of the Farnborough district, shows well the shape of the ground and the arrangement of the beds in the western part of this district.

Haslemere is on Lower Greensand, at the junction of the Hythe Beds, (sandy and stony), with Atherfield Clay. The houses are built on the pervious strata beds, of which there is here but a small thickness above the clay. *Witley*, *Thursley*, and other places, are also on the Hythe Beds, at good elevation, the clay having a good slope beneath the pervious beds. *Bramley*, *Wonersh*, and *Elstead* are similarly placed, on gravel at the edge of streams. On the Weald Clay, *Crawley* and *Chiddingfold* are the chief places; the former lies low, and is necessarily wet; the latter is on some slope towards a stream.

Estimated number of population living on Lower Greensand, 6,837, all of them on sandy beds; on Weald Clay, with more or less gravel, 2,820; on Weald Clay without gravel, 4,250.

Phthisis death-rate for males - - -	275
„ „ females - - -	411.

[29.] BATTLE, Sussex. Acres, 54,000. Population, 12,680. Map. 5.

Battle.

The whole district is on the Hastings Beds of the Wealden series; nearly half is Wadhurst Clay; there is a little alluvium, and the rest (more than half) is sand. The general contour is a ridge running from N.W. to S.E. through the centre of the district, with irregular subordinate ridges with streams in the valleys between them. The elevation of the ground is moderately high, its highest part being 600 feet.

Battle is on a moderate hill, at the edge of a bed of clay. The ground sloping from the town on the N.E. is sand, on the S.W. clay. There is good surface drainage, and the underground drainage is probably a good deal facilitated by the adjacent ground being faulted. *Bexhill*, the next largest place, lies with neighbouring parts, on a hill of sand over clay (100–150 feet elevation), and the surface slopes down from it in all directions. *Seddlescombe* is on sand, sloping to a brook. The villages generally stand on high ground, and not immediately upon streams. In this position they have excellent facilities for natural drainage.

Estimated population living on clays of the Hastings Beds, 2,500; the remaining 10,180 being on the sands of that formation.

Phthisis death-rate for males - - -	250
„ „ females - - -	338.

[30.] CANTERBURY, Kent. Acres, 3,121. Population, 16,643. Map 3.

Canterbury.

The registration district includes only part of the city, which extends into Bridge and Blean districts. The district lies on the right bank of the Stour, and part of it on an island formed by the division of the river. The streams here are greatly dammed up, and the houses are built quite to the edges of them. The range of elevation in the city is from 35 to 25 feet above the mean level of the sea. The island and some parts beyond the eastern division of the river are on alluvium, and are subject to be flooded. From this flat tract rises a gentle slope of gravel and made earth, and on these the cathedral and the greater part of the town

stand. At the south-east chalk comes to the surface, and at the north-east Thanet Beds capped by gravel. On these formations houses are built in the outskirts of the town. Any artificial drainage that has been done in the city, and it is too recent to affect the rates on which this inquiry proceeds, can have had little effect on subsoil, as the milldams are preserved, and the town is still liable to floods at its lowest levels. Wells in the town are supplied from the superficial porous strata, largely assisted by percolation from the river. Water is reached at 6–10 feet below the surface. The barracks get a copious water supply from the chalk.

Approximate number of residents on alluvium, 1,600; on Lower London Tertiaries, 3,000; and on Chalk, 12,043.

Phthisis death-rate for males - - -	441
„ „ females - - -	328.

Note the presence of the Kent and Canterbury Hospital as a slight cause of artificial increase in these rates. Note also the barracks (1,597 soldiers) and the county prison (93 inmates). Mr. Reid, of Canterbury, has enabled correction to be made for the deaths of persons dying in these establishments, and not having previously resided in the district. Thus corrected, the male rate becomes 400, and the female 298.

[32.] Hollingbourne, Kent. Acres, 57,017. Population, 13,584. Maps 3 and 6.

Hollingbourne.

Consists (*a*) in its northern half of a Chalk country, about 600 feet high at the escarpment, and falling thence northward with a gradual slope; and (*b*) in the southern half of a narrow strip of Gault with a broad band of Lower Greensand (sand and limestone), forming a rising ground near the Chalk escarpment; and (*c*) a flat of Weald Clay, wet and low, with patches of gravel over it.

Lenham, *Boxley*, *Hollingbourne*, with smaller villages, lie at or near the bottom of the Chalk escarpment, partly on the Chalk, partly on the gault. *Stockbury* and other places are on Chalk. The two *Suttons*, *Leeds*, &c., are on the lowest beds (Kentish Rag over Atherfield Clay) of the Lower Greensand, high, on a good slope. *Headcorn* is a village on the Weald, bordering a brook, and lies low, with a slope of only some 15 feet in a mile.

The population living on chalk is about 4,330; on gault, 1,250; on Lower Greensand, 5,074; on Weald Clay, 2,930, of whom 500 are on more or less of gravel.

Phthisis death-rate for males - - -	310
„ „ females - - -	394.

[33.] Malling, Kent. Acres, 47,398. Population, 21,447. Map 6.

Malling.

On the north this district has a narrow portion of the chalk escarpment; then a belt of Gault lying at a much lower level and wet: then follows a broad tract of Lower Greensand (sand and Kentish Rag), gradually rising upwards to the south to a height of 400 feet, and having on it the greater part of the population. On the extreme south there is Weald Clay, slightly covered with gravel, mostly over 100 feet above datum, and in some parts as much as 200 feet.

Wrotham is the largest place; it stands high, on chalk, at the foot of a hill near gault. *Snodland* is low, on gault, where some gravel covers it, at the edge of the Medway. *Burham* and *Trottersclife* are also on gault.

West Malling and many other villages are scattered over the Lower Greensand country, from the Gault to the Weald Clay; all are on fair slopes. The two *Peckhams*, *Wateringbury*, and *Mereworth* are at or near the junction of the Kentish Rag with Weald Clay; but their elevation appears such as to allow of natural drainage. *Aylesford* is lower, on gravel over sand (Folkestone Beds), bordering the Medway.

Small villages only, of no consequence, are on the Weald Clay, mostly where there is some gravel over it.

Of the whole population, the approximate number on alluvium is 100; on chalk, 2,780; on gault, 1,630; on Lower Greensand (its pervious beds only), 13,300; on Weald Clay with gravel, 2,220, without gravel, 1,417.

Phthisis death-rate for males	-	-	- 290
„ „ females	-	-	- 423.

[34.] EAST ASHFORD, Kent. Acres, 54,498. Population, 12,286. Maps 3 and 4.

East Ashford.

At the extreme north a few houses stand on some high-lying Tertiary Sands. The northern third of the district is Chalk (with irregular cappings of clay and loam), at its usual high level. Across the middle, from east to west, runs a band of Gault clay covered, between Wye and Ashford, by a thin layer of loam or gravel, whilst on the east of the Stour it is lower and more wet. Then to the south, about half the district is Lower Greensand (sand, sandy clay, and limestone), and at the edge of Romney Marsh it comprises a little Weald Clay.

There is no place of 2,000 inhabitants in the district. *Wye* and *Kennington* are on slight slopes of gault at the junction with the chalk, parts of their sites being capped by gravel. The river Stour runs by Wye, and provides the gravel waters with ready exit. *Brabourne* and *Brook* are on slopes of gault without gravel. Other villages along the valley of the Stour are on chalk or on gravel, or caps of clay over it.

Willesborough, a largish village, and other smaller ones, are on more or less pervious beds of Lower Greensand, generally on a rise. At the extreme south are several villages upon Weald Clay bordering alluvium.

Approximate number of residents on alluvium, 200; on Lower London Tertiaries, 100; on Chalk, 3,650; on Gault, 2,480; on Lower Greensand, clayey parts, 600, sandy parts, 2,520; on Weald Clay without gravel, 2,486; on Hastings Beds, 250.

Phthisis death-rate for males	-	-	- 262
„ „ females	-	-	- 456.

Observe the striking difference in the rates of the two sexes.

[35.] SEVENOAKS, Kent. Acres, 67,488. Population, 22,039. Map 6.

Sevenoaks.

At the northern part of the district there is a little Chalk, at a high level, and partly covered with loam. Next a strip of Gault, about a mile broad (with an insignificant outcrop of Upper Greensand), crosses from west to east. Then comes a broad band of Lower Greensand, rising southwards to its escarpment (where the Kentish Rag is at a height of from 500 to 700 feet), succeeded by another broad band of Weald Clay. This is mostly flat, with very little gravel. The central parts lie at 100 to 200 feet above Ordnance datum, the southern part less, and the northern more (from 300 to 400 feet near the greensand escarpment). The southern quarter of the district includes various beds of the Hastings series, and of this about half consists of Wadhurst Clay, or is covered by alluvium.

Sevenoaks stands at a fair height, on the upper division (Folkestone Beds) of the Lower Greensand, on a pervious soil underlaid by the also pervious Kentish Rag. *Westerham*, on similar formations, is in a valley. These are the two largest places. *Sundridge*, *Brasted*, and other villages lie much like Westerham, and have besides more or less gravel along the stream in the valley. Water is probably near to the surface here. *Seal* is situated at a greater height on the same beds. *Edenbridge* is on Weald Clay on a river where there is valley gravel, but this place too is low. *Leigh* is a village on a slope of Weald Clay. *Penshurst*, on the country of the Hastings Beds, is on gravel over sand between two streams, where the ground is low and wet.

A section, No. 77, very recently published by the Geological Survey, shows instructively the contour of the country hereabouts, and the geological relations of the surface. It runs from Groombridge, on the boundary of Kent and Sussex, northward, along the west edge of the district, to Eynesford in the Dartford district. The county boundary is a brook, the watercourse being formed by drainage from a slope of Wadhurst Clay meeting the softer Tunbridge Wells Sand at a fault. For two and a half miles northward of this boundary the Wadhurst Clay, slightly troughed, is covered by Tunbridge Wells Sand and an outlier of Weald Clay, rising to a hill of some 400 feet. The valley of the Medway (100 feet above datum) is here formed by Ashdown Sand, flanked by Wadhurst Clay on either side. The Ashdown Beds, with Wadhurst Clay over them, rise on the west of the Medway to Rogues Hill, 250 feet high. To the north of the river the section runs through about four miles of Weald Clay, in which extent the differences of elevation do not amount to more than 30 or 40 feet. The South-eastern Railway is crossed by this section at a point about 160 feet above datum. [In the west to east course of that railway through the Weald, about eight miles are in the Sevenoaks district, at a part where the Weald Clay is more than usually undulating. There are six cuttings and three or four embankments in this distance; the common extremes of height are 200 and 140 feet, but one spot is only 105 feet high, where there is a stream and gravel.] In all the Weald Clay tract, except at the edges of streams, there are only scattered farms and hamlets. The northern edge of Weald Clay rises considerably near the junction with the Lower Greensand, where the altitude of 500 feet is rapidly reached, to which the Lower Greensand in the course of another quarter mile adds 200 feet more. From this point northward the Lower Greensand slopes down gradually with the dip to its junction with gault. This, with a thin band of Upper Greensand, begin a slight rise, upon which follows the great Chalk escarpment at the extreme north of the district.

Approximate number of residents on alluvium, 100; Chalk, 1,830; Upper Greensand, 510; Gault, 925; Lower Greensand (all pervious beds), 10,200; Weald Clay with some gravel, 1,220; the same without gravel, 3,640; Hastings Beds, 3,614, viz. 1,000 on clays, and 2,614 on sands.

Phthisis death-rate for males	-	-	- 295
,, ,, females	-	-	- 427.

[36.] GUILDFORD, Surrey. Acres, 65,592. Population, 29,330. Map 8.

Guildford.

The northern half of this district consists of low-lying Tertiary beds, Bagshot Sands, London Clay, and Reading Beds. This Tertiary part is moderately undulating; within 7–8 miles the road from Guildford to Ripley shows elevations of 160, 106, 140, 84, 85, and 140 at six points pretty nearly equidistant. Across the middle, from east to west, runs a ridge of Chalk with very narrow bands of Upper Greensand and Gault parallel to it. The southern third of the district is a tract of Lower Greensand (with an inlier of Atherfield Clay and Weald Clay on the south of Guildford, covered by sand and gravel), and this part is well placed for height and natural drainage.

The town of *Guildford* is in the main on chalk, where the ridge is cut through by the valley of the Wey. Its elevation ranges from 300 to 140 feet. A portion of Stoke parish, comprised in the town, is on Reading Beds, at a very small slope. With this exception the town is on a slope, and dry. *Godalming* is the second largest place; situated on gravel and Lower Greensand close to a river, and rising gently (about 40 feet in a half mile) from the river. A part on alluvium has scarcely any houses on it.

Woking and some other places are on low-lying gravel and Bagshot Sands, between streams. The edge of Woking is on alluvium. *Worplesden* and *Pirbright* are on the middle and more clayey division of the Bagshot Beds, and are at a low level. A number of villages, *Horsleys* (2), *Clandons* (2), and *Merrow*, are placed at the junction of the Tertiaries with the chalk, parts extending over to the London Clay. *Shere*, *Compton*, and other places are on the pervious beds of the Lower Greensand, slightly sloping upwards from streams.

Approximate number of persons living on alluvium, 370; on Bagshot Sand, 5,450 (of whom 1,200 may be taken as on the clayey Bracklesham division thereof); on London Clay covered by gravel, 2,200; on the same without gravel, 2,550; on Lower London Tertiaries, 1,350; on Chalk, 8,200; on Upper Greensand, 20; Gault, 40; and Lower Greensand, 8,760 (the Sandgate Beds thereof being unrepresented); on Weald Clay, 380, of whom 280 live on more or less gravel over the clay.

Phthisis death-rate for males - - -	359
„ „ females - - -	379.

[37.] FARNBOROUGH, Surrey and Hants. Acres, 39,571. Population, 14,318. Maps 8 and 9.

Farnborough.

This district is cut into three parts by the Farnham registration district, with which it agrees in its chief geological features.

There is no town of any magnitude here. *Farnborough*, with the *North Camp* of *Aldershot*, is on Bagshot Beds, part of the village itself being on alluvium, but the camp being on a fair elevation, and dry. Other villages are in a similar situation. *Headley* and *Bramshott*, two of the largest villages, are on Lower Greensand.

Estimated number of population living on alluvium, 200; on Bagshot Beds (of whom 500, besides some of the military, may be taken as living on the Bracklesham division) 8,620; on uncovered London Clay, 1,320; on Lower London Tertiaries, 500; on gault, 100; and on Lower Greensand (without clay), 4,128.

Phthisis rate for males - - - -	201
„ „ females - - - -	381.

Note special occupation of 3,029 of male population, any of whom when they are ill are sent out of the district to hospital. To obtain a truer mean rate for the sexes, the average difference between the mean rate and the female rate observed in the south-eastern counties generally (and amounting to 10 per 100,000 yearly) has been subtracted from the registered female rate, and the adopted mean rate of 371 has thus been obtained.

[38.] EASTRY, Kent. Acres, 50,710. Population, 25,900. Map 3.

Eastry.

The northern part of this district, about one-third of the whole area, is on Tertiaries, chiefly consisting of sand, with small slope and northward dip. The southern two-thirds are chalk, also sloping and dipping

northwards, with thin sandy or loamy soil in parts. On the north-east is a strip of marsh.

Deal—the whole sea face and the main part of the town are on shingle and seasand; some inland parts are on sandy brick-earth over Chalk, and Upper Deal is on Chalk itself. Most of the town is very low, and protected by the sea bank; its elevations range from 22 to 9 feet above mid-level of sea, and parts are therefore below high-water mark. The beds under the town are pervious but waterlogged, and the lower parts of houses get flooded in spring tides or storms. Some drainage recently done has probably improved the town in this respect. *Sandwich* is almost on an island of Thanet Beds (sand over sandy marl), and small parts are perhaps on shingle. The town is at a very small elevation (from 26 to 14 feet), with river on two sides, and marsh on the others. *Ash*, *Woodnesborough*, *Preston*, and other places are on Tertiary (Thanet and Woolwich) Sands, at more or less elevation, and necessarily dry soil. *Wingham* and *Staple*, being on the lower more marly parts of the Thanet Beds, and lying in a valley, may be more wet. *Walmer*, *Eastry*, and many other villages, furnishing about half the population of the district, are on chalk at various elevations; some with a loamy soil over the chalk. But everywhere here the chalk is dry, the valleys even having no streams.

Approximate number of residents on alluvium, 460; on shingle and sea-sand, 5,500; on Lower London Tertiaries, 6,850; on Chalk, 13,090.

Phthisis death-rate for males - - -	357
„ „ females - - -	385.

The marine hospital and barracks at Walmer are a possible disturbing element to this rate, but can operate only to an insignificant degree.

[39.] Faversham, Kent. Acres, 46,448. Population, 18,867. Map 3.

Faversham.

A district mainly of Chalk, sloping downwards with the dip from south to north, with valleys and ridges running in the same general direction. On the Chalk is an irregular thin capping of clay, and there is gravel in the valley bottoms. The eastern fifth of the district and a portion near the Thames estuary are Tertiary; the eastern part being high wooded hills with nearly level tops and a sharp slope downwards on the west, formed by gravel-covered London Clay at the top, and the Lower London Tertiary Sands cropping out at the foot. Near the river also are Tertiary Sands and clay with drift brick-earth and gravel and low flats of alluvium. This is the most populous part.

Faversham is situated at the junction of the Tertiaries and Chalk, on Thanet Sand and marl and brick-earth. It is at the head of a creek, with very slight slope to the river. Its levels range from 30 to 45 feet above mid-level of the sea, but it is generally flat. Parts of adjacent parishes are similarly placed.

Teynham is on brick-earth and Thanet Sand, at the edge of a marsh, in a wet situation; other villages are on rising ground bordering marsh land. On the Chalk hills and valleys are several small villages. On the slope of the chief wooded hill, on Tertiary Sands at 80 to 40 feet high, stands the large village of *Boughton-under-Blean*. *Harbledown*, at the extreme east, is a suburb of Canterbury, on the side of a hill of Tertiary Sands.

Approximate number of residents on alluvium 350; on London Clay without gravel, 480; on Lower London Tertiaries, 5,850; on Chalk, 12,187.

Phthisis death-rate for males - - -	312
„ „ females - - -	429.

In Faversham there is some ague, less of late years than before the period to which the above rates refer. But there was an increase in 1859.

[40.] RYE, Sussex. Acres, 39,369. Population, 11,927. Maps 4 and 5.

Rye.

A district formed for the most part by the Hastings Beds of the Wealden. These consist of sands and clays (the area being about half sand, half clay and alluvium) with a long fault through them from east to west, and other smaller faults. This part is of good elevation and undulating, but river valleys with alluvium bound it on the north and south and partly intersect it. To the east a part of Romney Marsh is included in this district, with deposits of shingle on the coast.

Rye is on an island of Ashdown Sand surrounded by marsh, and rising 60 feet above the marsh; there is a little capping of clay on the surface. The higher parts must have good natural drainage. *Winchelsea* is on a peninsula of the same description, on a considerable rise with a cliff to the sea. Its situation appears to be dry. The marsh around these places consists of a flat of the Ashburnham Beds (sandy clays at the bottom of the Hastings series) covered by alluvium of estuary origin. Rye and Winchelsea, the chief places of the district, are close to the sea. Other places are *Northiam*, on sand above Wadhurst Clay, on a hill; *Beckly* and *Peasemarsh*, similarly placed but apparently farther from clay; and *Brede*, on Wadhurst Clay. The circumstances of the soil in these places is mostly favourable to the retention of water. The population of the district is largely seafaring.

Estimated number of population living on alluvium, 300; on shingle, 100; on clays of the Hastings series, 2,000; on the sands of the same, 9,471; and on board vessels there were 56 persons.

Phthisis death-rate for males - - -	315
„ „ females - -	438

There was once on a time much ague here, with an accession in 1859; less since then.

[42.] MAIDSTONE, Kent. Acres, 38,082. Population, 38,670. Map 6.

Maidstone.

The northern part of this district is Lower Greensand, forming a tolerably high country, rising to the south, well drained, and intersected by the valley of the Medway. The southern part of the district is lower, 50 to 100 feet, and is of Weald Clay capped by gravel and loam over nearly half its area: this part is cut through by various rivers with alluvium along them; where there is gravel it is dry, but the rest is wet, and near Yalding is much subject to floods.

Of the town of *Maidstone*, more than half is placed on an inlier of Weald Clay and Atherfield Clay cut through by the Medway and another stream, and almost wholly covered by gravel. The highest part of the town is its triangular periphery of pervious Hythe Beds over Atherfield Clay. The soil of the lowest parts of Maidstone must be wet to the level of the river (which is here tidal); and other parts at the junction of the clay and pervious beds are also in a position to have their soil saturated. This may locally have been less since the adjacent railway cutting was made through the edge of the clay, when trouble arose through a brewery well having been dried by this work. *Loose* is a large village situated on a slope of the Hythe Beds, and on

an inlier of Atherfield Clay without a river, and at a lower level than Maidstone. There are a few villages (of which *Brasted* is the chief) on other parts of the Lower Greensand district, but the chief remaining places are on the Weald Clay. Of these *Marden* has a good deal of gravel over the clay, and stands at some elevation; at *Staplehurst* there is less gravel; and part of *Yalding* stands on alluvium.

Approximate number of dwellers on alluvium, 300; on Lower Greensand, 16,700 (none to speak of being on the Sandgate Beds); on Weald Clay covered by gravel, 17,530; on the same without gravel, 4,140.

Phthisis death-rate for males - - -	394
„ „ females - -	475.

Correction has been made in these rates for persons dying of phthisis in the Kent County Lunatic Asylum who had their previous residence beyond Maidstone, and the corrected rates are males, 354; females, 405.—Ague was common in this district, both in the town and villages, in 1859; at other times it has been rare. The year 1859 was particularly dry, "exposing surfaces to evaporation that commonly remained moist." The town was being drained in 1863.

[43.] Cuckfield, Sussex. Acres, 61,793. Population, 17,163.
Maps 5 and 9.

Cuckfield.

A large rural district, thinly populated. The northern and larger parts is of sands and clays (mostly sands) of the Hastings Beds, much faulted. The Tunbridge Wells "Sands" are here much divided by clays and loams, and are overlain in places by patches of Weald Clay. The southern part is a vale of Weald Clay (low and wet), with Gault, Greensand, and Chalk at the extreme south.

Cuckfield, *Lindfield*, *Slaugham*, and a number of other places are on the Hastings Beds, mostly on the sandy members of the series. Cuckfield is a good instance of the variety of soil that is met with within a small area in these Hastings Bed districts. It stands on a double sandwich, as it were, of clay and sand; the highest clay being an outlier of Weald Clay, the other two sands and two clays being members of the Hastings Beds, and all much faulted. Thus, though the ground is high, it is impossible to say what part live on dry and what on wet soil. Certainly this town and most of the villages on the same formation must have many springs and much wet soil.—Villages on the Weald Clay area are near brooks, and are low and damp. *Hurstpierpoint*, on somewhat rising loamy sand of the Lower Greensand, and other places near the edge of the Weald, on the same formation, are also likely to be wet. Small places at the junction of Chalk and Upper Greensand stand quite well for dryness.

Estimated population living on Chalk, 550; on Upper Greensand, 360; on Gault, 30; on Lower Greensand, 2,910 (of whom perhaps 200 live on Sandgate Beds); on Weald Clay without gravel, 4,262; on the clays of the Hastings Beds, 850, and on the "sands" of the same series, 8,200.

Phthisis death-rate for males - - -	304
„ „ females - -	471.

[44.] Dorking, Surrey. Acres, 40,006. Population, 12,445.
Map 8.

Dorking.

On the north a small part of this district is high Chalk with local cappings of surface clay and loam. A narrow band of Upper Green-

sand and Gault, and a broadish band of Lower Greensand (represented here by pervious beds only) cross the district from east to west. The southern part, about half the area of the district, is Weald Clay, which forms as usual a wooded plain flat or with very slight undulations only, but at its junction with the Lower Greensand rises more sharply, and Leith Hill, formed by the Greensand over Weald Clay, is the highest ground of the south of England, reaching nearly 1,000 feet above Ordnance datum.

The town of *Dorking* is mainly on a slope of Lower Greensand, some of its lower parts being on gault covered by much gravel. The lower lying parts are but little above the saturation level of the Lower Greensand. Other places are similarly situated in a valley of this last formation. On the north are some villages at the junction of the chalk and Tertiaries, and others in the valley of the Mole on chalk. On the south there are many villages and hamlets on the Weald Clay area.

Estimated population on London Clay (without gravel), 100; on Lower London Tertiaries, 230; on Chalk, 1,020; on Upper Greensand and Gault (each), 50; on Lower Greensand (all sandy), 7,065; on Weald Clay, 3,930, of whom 100 live on spots that have gravel.

Phthisis death-rate for males -	-	321
„ „ females	-	478.

[45.] UCKFIELD, Sussex. Acres, 74,230. Population, 17,260. Maps 5 and 6.

Uckfield.

A district wholly rural, and composed almost exclusively of Hastings Beds, much faulted, with more of the sands than of the clays of that series, in the proportion of about 4 to 1 of area. In the eastern part, however, the Tunbridge Wells Sand is loamy. The country rises to its highest ground (600 feet) on the north, and is much intersected by streams at levels of about 120 feet or thereabouts above datum. There is a very small piece of Weald Clay at the south-west.

Rotherfield and *Mayfield*, the two largest places, are on slight hills of Ashdown Sand and Tunbridge Wells Sand respectively. The former is well placed for natural drainage, but at Mayfield the sand may have water kept up in it by the underlying Wadhurst Clay. *Buxted* is placed much like Mayfield, and *Waldron* like Rotherfield. *Uckfield*, *Maresfield*, and *Fletching* are on slopes of sand near to streams. *Framfield* stands on a slight hill of Wadhurst Clay. On the whole, except for the retentive character that the Hastings Sands have in particular localities, this district would not be supposed to have much wet soil, at any rate in such parts as are most inhabited. It is difficult to see any serious difference in physical or geological features between Uckfield and Battle, which has a far smaller phthisis rate.

Approximate number of population living on alluvium, 60; on uncovered Weald Clay, 200; on clays of the Hastings Beds, 3,000; on sands of the same, 14,000.

Phthisis death-rate for males -	-	312
„ „ females	-	484.

[46.] HAILSHAM, Sussex. Acres, 54,365. Population, 12,668. Map 5.

Hailsham.

A district high at the north, reaching 500 to 600 feet, but sloping down to the marsh of Pevensey Level at the south. The northern half is of Hastings Beds, which here are mainly sandy (Tunbridge Wells and Ashdown Sands), and sloping (Wadhurst) clay. The southern half is Weald Clay with marsh land.

Hailsham, the most populous place, is on a very slight rise of Weald Clay about a mile from the marsh; other smaller places are also on the Weald Clay. *Herstmonceux* and *Worthing* are on a slight rise of sand, quite at the edge of the marsh, and have brooks all round them. *Heathfield* and *Warbleton* are high, on Ashdown Sand. Other places stand on other parts of Hastings Beds, or on the junction of these with Weald Clay.

Of the total population, it is estimated that 50 live on alluvium, 40 on Gault, 70 on Lower Greensand, 4,290 on Weald Clay without gravel, 500 on clays of the Hastings series, and 7,718 on the sands of the same series.

Phthisis death-rate for males - - -	270
„ „ females - -	535.

There is no known reason why the female rate should be in so very great excess of the male. But the same fact will be observed in most of the districts that have high rates.

[47.] Ticehurst, Sussex. Acres, 51,659. Population, 14,626. Maps 5 and 6.

Ticehurst.

This district is entirely of Hastings Beds, nearly half being Wadhurst Clay. There is considerable range of elevation, from 600 feet at Frant to 250 at the north-west (where part of Tunbridge Wells town is in this district), and even to 50–100 feet on the south and south-east. The northern tract, which is the highest and most sloping, is (as regards all its inhabited parts) of Tunbridge Wells Sand. The southern has much wet clay soil, but is not flat or low.

Frant, just mentioned, is a large village, high and dry. *Ticehurst*, of like size, is partly on the Tunbridge Wells Sands, partly on Wadhurst Clay, and near a considerable fault. The surface of the clay is in slopes, but in the sandy parts water is probably held up. *Burwash* stands on an outlier of sand over clay, also on moderately high ground. It is the habit of clay so placed to form slight troughs or hollows, and to keep the porous soil over it wet. *Wadhurst* is at the junction of clay over sand, on a hill, and in a dry situation. *Lamberhurst* lies low, by a stream, on sand over clay, where there is some alluvium.

Estimated population on clays of the Hastings Beds, 4,800; on sands of the same, 9,826.

Phthisis death-rate for males - - -	346
„ „ females - - -	457.

There is a large private lunatic asylum here, but it does not affect the above death-rates.

[48.] Worthing, Sussex. Acres, 42,457. Population, 18,921. Map 9.

Worthing.

Consists mainly of Chalk, dipping slightly from the sea to the north, and also from the escarpment to the south. At the north a small part is Upper Greensand and Gault, and near the south a narrow strip of Tertiaries runs from east to west across the district. The whole is cut through from north to south by the river Arun, with a broad belt of alluvium, and some little gravel locally mixed with clay.

The Chalk at the northern part of this district makes, as usual with that formation, a high and sloping country, but the broad tract of chalk facing the sea, and upon which the bulk of the population reside, is largely covered by loam and gravel, and lies very low, only a few feet above high-water mark.

Worthing is the largest place, and stands on loam and clay over Chalk, the main part of the town on a flat of 18–20 feet elevation, and water used to be reached wherever a trench was dug. In 1853–6, soon after the beginning of the period to which the subjoined phthisis rates refer, sewerage works were carried out in Worthing with the effect of lowering the water-line under the town. *Littlehampton* and many other villages are on the same low-lying Chalk, with more or less surface gravel and brick-earth, at no great distance from the sea. At *Poling*, two miles from the coast, the Chalk has only risen to 20 feet above mid-level of the sea. On the higher-lying Chalk the chief place is *Arundel;* here the chalk is almost uncovered, and the town is on a considerable slope towards the river, part being on river alluvium. *Broadwater* is on a Chalk slope 48–32 feet high. Other villages are in the valley of the Arun, on gravel over low-lying Chalk, and others on the chalk just off the alluvial edge of the river. *Buxted* and *Amberley* are villages on the Upper Greensand, the latter being near a marsh.

Estimated population living on alluvium, 550 ; on blown sand (classed with shingle), 200; on Lower London Tertiaries, 420 ; on Chalk, 17,296 (the great majority being on the low gravel-covered plain) ; on Upper Greensand, 440; and there is a detached morsel, with perhaps 15 people, on Weald Clay.

Phthisis death-rate for males	-	-	- 393
„ „ females	-	-	- 445

Note that in the town of Worthing itself the mortality from consumption among residents at the ages of 15–55 has fallen since the sanitary operations of 1853–56: the degree of this reduction being for males 11, and for females 41 per cent. of the previously existing rate of mortality.

[49.] WEST ASHFORD, Kent. Acres, 41,901. Population, 15,137. Maps 3 and 6.

West Ashford

The southern two-thirds of this district is formed by Weald and Atherfield Clay, mostly low and flat. The broad band of Lower Greensand which follows is here largely represented by the clayey Sandgate Beds. Then comes a narrow band of Gault, and at the northern extremity of the district a little Chalk. Perhaps not more than one-sixth of the area is formed by pervious beds.

The undulations of the Weald Clay country are shown on the line of the South-eastern Railway, from west to east, through this district. There is in the part of maximum range a difference of from 100 to 140 feet in the course of a mile, but the slopes are mostly about 20 feet in a mile, and are many and in varied directions, with streams in the lower ground.

Ashford town contains a third of the population of the district. It is on a slight rise of gravel underlaid by sands and clays of the Lower Greensand ; directly outside the town, and on three sides of it, the Atherfield and Weald Clays crop out, and probably form a slight basin below the town. *New Ashford*, on the other side of the river Stour, is mostly on flat clay. *Charing* and *Westwell* are on a high level at the base of the Chalk escarpment, where the Chalk is apt to be marly, and its water to be held up by the underlying Gault. *Bethersden*, *Smarden*, and other villages are on the plain of Weald Clay, Smarden being on a small flat of gravel. Other places are on the Lower Greensand; a few scattered houses only are on Gault.

Approximate population on alluvium, 100; on Chalk, 1,267 ; on Gault, 400 ; on Lower Greensand, 7,490 (viz., 3,000 on clayey beds, and

4,490 on the sands of this series); on Weald Clay without gravel, 700; and on the same with some gravel, 5,180.

Phthisis death-rate for males	-	-	300
„ „ females	-	-	542.

[50.] Lewes District, Sussex. Acres, 85,104 Population, 26,995. Maps 5 and 9.

Lewes.

Four poor law unions are comprised within this district, which extends from the sea some eight miles or more inland, and along the coast for 10–12 miles. The southern half is chalk, rising into four masses of hill divided by valleys, three of which have tidal streams in them, bordered by considerable tracts of alluvium. Across the district, from east to west, bands of Upper Greensand, Gault, and Lower Greensand run, forming a low flat district very unlike the greensand areas to the north and west, and only moderately dry. Then follows on the north a vale of Weald Clay, flat and wet; and at the extreme north there is an area of Tunbridge Wells Sand, which slopes southward, and contains some loam and clay. This part is less dry than the similar bed farther to the east (Uckfield, &c.). Both the Gault and the Weald Clay are so arranged that they throw out the water from the Greensands over them.

The population is but little on the high Chalk; but many villages along the edge of alluvium, in the Ouse valley, are on Chalk; water must be near the surface in most of them. *Lewes*, by far the most populous place, lies at the junction of these Chalk valleys, on a sluggish river which is tidal up to a lock above the town. Part of the houses are on chalk, rising to 100–150 feet, but most on low-lying chalk covered by gravel and alluvium that must be waterlogged. *Newhaven* is situated much like Lewes, but close to the sea. *Ditchling* (observe the name) is on the flat Lower Greensand, mainly on Sandgate Beds. There are villages on all the other formations that are above described.

Number of population estimated to live on alluvium, 1,100; on chalk (mostly low and gravelled), 16,180; on Upper Greensand, 1,750; on gault, 250; on Lower Greensand, 2,250 (of whom 750 are on Sandgate Beds); on Weald Clay, 2,785 (of whom 30 may be on a little gravel; on Hastings Beds (all sandy), 2,680.

Phthisis death-rate for males	-	-	496
„ „ females	-	-	508.

Deduction from these rates is required for persons belonging to other districts who died of phthisis (1) in the Invalid Convict prison, 1857–59; and (2) in the Sussex Lunatic Asylum at Haywards Heath. Of the convicts 42 males, and of the lunatics 30 males and 30 females, have been taken out of the numbers on which the above rates are founded, and the corrected rates become—for males, 388; and for females, 464. There has been little ague in the town of Lewes of late years, but it has prevailed, during the period under review, at Glynde, Beddingham, Piddinghoe, and other places. Its reduction is ascribed to better drainage of land.

[51.] Tenterden, Kent. Acres, 46,889. Population, 10,947. Maps 3, 4, 5, 6.

Tenterden.

About three-quarters of the district consist of clay and alluvium, and one quarter of sand. The north-eastern part is Weald Clay, low, flat, and wet; the southern part is on the clays and sands of the Hastings

series, which are much faulted and intersected by rivers with alluvial flats, forming a country of very various elevations. Such river flats bound the district for more than half its circumference.

Tenterden is the largest place, having a third of the whole population. It is on a hill of sand, which is here very clayey (Tunbridge Wells Sand and Grinstead Clay), over a flat or slight trough of Wadhurst Clay. Another third of the population, in the villages of *Biddenden*, *High Halden*, and *Woodchurch*, is on Weald Clay; all those places lying flat, and more or less low. The remaining population is mostly on Hastings Beds. *Appledore* is on sands, close to the alluvium of Romney Marsh; and other villages, *Rolvenden*, *Wittersham*, and *Stone*, on Wadhurst Clay, at various small elevations.

Of the whole population, estimated number living on alluvium, 30; on Weald Clay without gravel, 3,200; on clays of the Hastings series, 3,200; on sands of the same, 4,517.

Phthisis death-rate for males	-	-	- 342
„ „ females	-	-	- 528.

[52.] HORSHAM, Sussex. Acres, 57,023. Population, 15,313. Maps 8 and 9.

Horsham.

Chiefly an area of Weald Clay underlaid by Tunbridge Wells Sands, which come to the surface in the eastern part of the district. A local band of calcareous sandstone in the Weald Clay (Horsham stone) forms a higher and drier district than the general tract of clay; but this includes some clay, and is not so pervious as even the Tunbridge Wells Sand.

Horsham itself, with nearly half the population, is low and flat, on the loamy Tunbridge Wells Sands, close to where they dip under the clay. Other places are on the plain of Weald Clay, which has many gentle undulations in it, 100–200 feet above Ordnance datum, but no continuous slopes.

Estimated population on Weald Clay (without gravel, but locally with Horsham stone), 8,563; on the sandy parts of the same (which are particularly noted as "loamy," though no population can be separated out as living on clays), 6,750.

Phthisis death-rate for males	-	-	- 362
„ „ females	-	-	- 518.

[53.] WESTHAMPTNETT, Sussex. Acres, 74,913. Population, 14,811. Maps 9 and 11.

Westhamptnett.

Consists of (1) a northern part, less than half the area, of bare chalk rising to high ground (700 feet), and then sloping sharply downwards to the northern boundary, where the Gault and Lower Greensand crop out; and (2) of a southern part of clayey Lower London Tertiaries, London Clay, and Bracklesham Beds (the middle and clayey division of the Bagshot), with a spur of chalk, forming a low ground more or less covered by gravel and loam, and intersected by streams with alluvium along them. Selsea is on the Bracklesham Beds, with gravel, which here are formed into an island by the sea on one side, and on the other by a stream and its low alluvial border.

About half the population lives on the low flat plain of Tertiaries near the sea. This plain appears, from such sections and elevations as can be had, not to rise more than 10 feet above the mid-level of the sea, and in many parts to be under high-water mark. Three or four miles inland the Tertiaries, rising to about 80 feet where they join the chalk, have several more villages on them, and there are others adjacent, on

the rising chalk with gravel. The higher chalk is very thinly inhabited, but there is a village on Upper Greensand and Gault. Of 39 places in the district not one has a population so large as 1,000.

Of total population, estimated residents on alluvium, 120; on Bracklesham Beds of the Bagshot series, 1,570; on gravel over London Clay, 4,120; on Lower London Tertiaries, 3,910; on Chalk, 4,711; on Upper Greensand, 120; on Gault 230; and on Lower Greensand, 30.

Phthisis death-rate for males - - -	366
„ „ females - - -	518.

Corrected for the deaths of persons who, after removal from this district, died in the Chichester Infirmary, these rates become—for males, 377; females, 521.

[54.] Midhurst, Sussex. Acres, 65,720. Population, 12,581.
Maps 8 and 9.

Midhurst.

A district formed partly by Weald Clay, at the extreme west end of the Weald district, but in its larger part by Lower Greensand, Gault, Upper Greensand, and Chalk. Taking the clays of the Weald and Gault, together with the clayey parts (Sandgate Beds) of the Lower Greensand, about half the area is on impervious beds, all of which form tolerably flat surfaces; and the other half on Greensands (sand and stone) and Chalk, which last forms high ground on the south.

Midhurst is a small town which, with many smaller villages, lies on the river Arun, on rather low ground formed by Lower Greensand, and principally by the clayey division thereof. The ground slopes, indeed, towards the stream, but is certainly spongy and wet. A line of villages, of which *South Harting* is the chief, lie on the Upper Greensand, some nearer to Chalk, others to Gault, most with springs near them. Some of these places may be wet. Two small places are on Gault, others on slight slopes of Weald Clay.

Estimated population on alluvium, 20; on Chalk, 410; on Upper Greensand, 1,770; on Gault, 200; on Lower Greensand, 6,681 (of whom 3,500 is the probable number of residents on Sandgate Beds); on Weald Clay without gravel, 3,500.

Phthisis death-rate for males - - -	372
„ „ females - - -	539.

[55.] Thakeham, Sussex. Acres, 33,599. Population, 7,567.
Map 9.

Thakeham.

The district is very various in its contour and geology. The southern third, the high part of it, is Chalk, a third Gault and Lower Greensand, and a third to the north is Weald Clay; the centre of the district is an alluvial flat. The Chalk rises to a hill of 800 feet, and is everywhere scantily inhabited. North of the chalk escarpment is a plain of Upper Greensand, Gault, and Lower Greensand, the last being chiefly represented by its clayey (Sandgate) member. It is part of this plain that is covered by alluvium. Then northward follow the Hythe Beds, sandy and calcareous parts of the Lower Greensand, sloping again gently downward; the Weald Clay then makes a second almost flat plain, about 70 feet above datum.

Pullborough is the largest village, and is on the pervious Folkestone Beds of the Lower Greensand, but at a low level, with clayey beds below, and at the edge of the marsh. Other places are similarly situated,

some even upon more gravelly spots of alluvium. *Storrington*, the second largest place, is on the same beds, but farther from the marsh. *Thakeham* and some other villages are on the Hythe Beds. At the two extremes there is a scattered population on chalk and on Weald Clay.

Estimated population on Chalk, 710; on Upper Greensand, 540; on Gault, 635; on Lower Greensand, clayey beds, 1,100, sandy beds, 3,290; on Weald Clay, without any gravel, 1,294.

Phthisis death-rate for males - - -	348
„ „ females - -	560.

[56.] PETWORTH, Sussex. Acres, 39,329. Population, 9,397. Maps 8 and 9.

Petworth.

A district wholly of Weald Clay, except a small part in the south-west corner, on which *Petworth* town, with about a third of the population of the district, stands. This is the calcareous part (Hythe Beds) of the Lower Greensand, fairly high and dry, and draining to a stream. All the rest of the district is low, flat, and wet.

Approximate number of residents on Lower Greensand (only sandy beds), 2,850; on Weald Clay without gravel, 6,547.

Phthisis death-rate for males - - -	415
„ „ females - -	509.

[57.] WESTBOURNE, Sussex. Acres, 32,886. Population, 6,957. Maps 9 and 11.

Westbourne.

Consists of two tracts of Chalk, and two of Tertiaries, alternating. The northernmost part is high-lying chalk (500 feet), but the Tertiaries, and the band of chalk between them, form a flat plain of 15–25 feet above Ordnance datum, covered by gravel and bordered by a creek. All this part must be thoroughly wet.

Westbourne is on London Clay and Woolwich Beds, rising slightly from a stream. *Borham* and *Chidham* are very low, near to creeks, on gravel-covered Chalk. *Funtington* and other villages, together including nearly half the population, are on dry high Chalk.

Approximate number of residents on London Clay (without gravel), 1,000; on Lower London Tertiaries, 1,697; on Chalk, 4,260.

Phthisis death-rate for males - - -	386
„ „ females - -	610.

The population of this district is such, that one death more or less each year represents a difference of 56 in the above rate for males and 58 in the rate for females.

[58.] CHICHESTER District, Sussex. Acres, 21,054. Population, 14,775. Map 9.

Chichester.

This district consists of several areas scattered about among other districts. The two chief areas are (1) that of Chichester city and its environs, and (2) the Sutton area. The former is low-lying London Clay and Reading Beds, capped by gravel and loam, with a slope within the city from 49 to 21 feet; the latter is mainly Lower Greensand, also Gault, Upper Greensand, and Chalk; and the valley of the Arun runs through it. Other areas comprise (3) *Bognor*, on low gravel-covered clay, and adjacent parts on low flat chalk; (4) *Bury*, on Upper Greensand, near a marsh; (5) *Greatham*, on gravel over Lower Greensand; (6) *Heyshott*, on almost flat gault.

Approximate number of residents on gravel-covered London Clay, 10,210; on Lower London Tertiaries, 1,550; on chalk, 300; on Upper Greensand, 1,000; on gault, 720; and on Lower Greensand, 995 (700 of whom are on Sandgate Beds).

Phthisis death-rate for males - - - 670
" " females - - 463.

Corrected for deaths in the Chichester Infirmary of patients brought from other districts, these rates become—for males 623, for females 450.

Districts that can hardly be classified.

Sheppey.

[1 ? ?] SHEPPEY, Kent. Acres, 31,083. Population, 18,494. Maps 2 and 3.

This district, which has by far the lowest registered phthisis death-rate of any in the south-eastern counties, is an island of London Clay, capped by gravel and Bagshot Sand on its highest levels, and bordered on the south and west by alluvium, with islets of London Clay rising out of it. The London Clay, which forms the bulk of the district, rises to about 150 feet, and forms sloping ground, except where it is covered at the highest parts by gravel and at the lowest by alluvium.

Sheerness contains two-thirds of the population of the district. It lies very low, at the extreme north-west point of the island, almost on the level of the Medway, on a plain of alluvium 8–9 feet thick, below which shingle is generally met with. This alluvium is a softish clay; if a trench be dug in it, brackish water generally rises to within a few inches of the surface. In Sheerness is the dockyard, which gives an exceptional sort of employment to the male population; here, too, are barracks, and a number of persons are enumerated on board vessels. *Queensborough* resembles Sheerness in its position, but is placed slightly higher, on a low island of London Clay. The parts of Minster parish beyond *Sheerness* town, and *Eastchurch*, *Leysdown*, and *Warden*, are villages on high ground, most, if not all of them, being on cappings of gravel or sand over the London Clay. Such sites are often retentive of wet, from the surface of the clay being slightly basin-like, but in these instances the edge of every such basin is more or less broken by the sea cliff.

Approximate number of the population of the district living on alluvium, 12,069; on Bagshot Beds, 1,000; on gravel over London Clay, 50; on London Clay without gravel, 3,800; on board vessels, 1,575.

Phthisis death-rate (registered) for males - 202
" " " females - 251.

Sheppey is a district for which the method of computation in the Parliamentary return gives inaccurate results. The population is rapidly increasing, and the arithmetical mean of the two censuses, from which the death-rate is calculated, is larger than the true mean upon which the death-rate ought to be taken. (See note to Kingston.) The death-rate therefore comes out unduly low. The census papers give evidence of considerable importation of males from 15 to 45 years old, and of some exportation of them after the latter age, a large proportion of the incomers being unmarried. The presumption is, that these people are of the healthier sort, and that if they were unable to work they would go away from the district to be nursed. Local information confirms the conclusion that the phthisis rate of males is thus artificially lowered.

The female rate is probably influenced in the same direction, but to a much less degree, by similar considerations. It is pretty clear that many females also spend only the middle period of their lives here, probably coming and going with their husbands, and in case of illness returning to their previous residence.—The military at Sheerness numbered 752, and with their wives and families 1,005, in 1861. They are treated when sick in the hospital attached to their barracks, but if they get phthisis are often discharged invalided and die in other districts. So far as they died in the hospital, their phthisis rate is just that registered for males in the district at large.

Ague was prevalent in the Isle of Sheppey during the period 1851–60. Of late years it has been reduced in Sheerness. At Minster and Eastchurch it remains about as common as formerly. Local medical opinion assigns less phthisis to Sheerness than to the other places where there is more ague.

[2 ? ?] HASTINGS, Sussex. Acres, 14,027. Population, 26,631. Map 5.

Hastings.

The district is from 300 to 400 feet high in its central parts, and the ground forms three hills with deep valleys running to the sea. It comprises the towns of *Hastings* and *St. Leonards* only. They lie on the lower beds of the Wealden series, which are grouped under the name of "Hastings Beds," and consist of alternations of sand and clay; in this case the area of the district being about two-thirds of sand and one-third of clay. The Castle Hill is Ashdown Sand, on which also the main parts of the town of Hastings are built. St. Leonards is chiefly on the Tunbridge Wells Sand, and partly also on Wadhurst Clay. There is great range of elevation within the inhabited parts of this town, and there must be very varying facilities for the natural drainage of particular parts, considering that some localities stand high, some low; most on sands, but some on clay. But the most parts must be dry.

Of the population about 1,300 only are estimated to live on the clays of the Hastings Beds, the remainder on sand.

Phthisis death-rate (registered) for	males	- 531
" " "	females	- 466.

Enquiry has been made by Dr. Greenhill, of Hastings, as to the mortality among persons frequenting this town on account of the repute its climate has obtained in consumption, and the result is that certainly more than half the registered mortality from this disease is among visitors. Of the male rate, 288 is accounted for by visitors, and of the female rate 259, reckoning the deaths on the male and female population aged 15–55, mean of two censuses. But as the numbers of visitors have not been ascertained at the censuses, the rate among residents cannot be computed by merely deducting these figures. Perhaps half the registered rates will be not far from the truth for consumption among residents. Its indigenous phthisis only would certainly place Hastings in a wholly different place among other districts than is assigned to it for its registered mortality from the disease. But of its true position relatively to other districts, it can only be affirmed that it must stand among the highest, perhaps even in the very highest place.

[8 ? ?] THANET, Kent. Acres, 29,733. Population, 31,862. Map 3.

Thanet.

Bounded for three-quarters of its extent by sea, and formed into an island by the Stour and Wantsome rivers, which are flanked by broad

marshes. Nearly the whole island is bare Chalk, with a foot or so only of loamy soil above it. Here and there are small patches of clayey Thanet Beds, and the edge of the marsh on the south is fringed by a thicker mass of this formation, consisting of sand and sandy marl.

Ramsgate is cut through by a valley running to the sea, with coarse gravel covering the Chalk at the bottom. On the western heights is a small capping of sandy brick-earth. Its elevations range from 125 to 16 feet above the mid-level of the sea. *Margate* is similarly placed, but a small part is on a flat of alluvium which runs inland from the harbour. With the exception of this part and some portions of the valley at Margate, there is excellent natural drainage of the subsoil in both towns. The range of altitude in Margate is from 150 to 14 feet. *Broadstairs* and the main area of the district are high and dry, on the Chalk. *Minster*, a large village, is on marly Thanet Sand and brick-earth at the edge of the marsh, in a wet situation.

Approximate number of residents on alluvium, 100; on Lower London Tertiaries, 1,300; on Chalk, 30,462.

Phthisis death-rate for males - - -	420
,, ,, females - -	364.

These death-rates are both somewhat raised (the male most so) by the presence of two infirmaries at Margate; but they are both further raised, to a great and unascertainable extent, by the practice of sending consumptive invalids to Margate in the late stages of their complaint. A letter from Dr. Price, of Margate, gives data which prove that 100, and probably more, should be deducted from each of the above figures for deaths among persons previously unconnected with the district.

[14 ? ?] Hoo, Kent. Acres, 33,281. Population, 2,861. Maps 1 and 6.

Hoo.

A very thinly populated district between the Thames and Medway, consisting of London Clay with local gravels, with an insignificant area of sandy Lower London Tertiaries cropping out on the north-west. The district has various elevations and slopes, its highest point being 200 feet; thus there will be fair surface drainage. On the north and east the district is bordered by marsh.

Hoo is the chief place, though only a village. It is on a thick bed of brick-earth and gravel, with a fair slope.

Of the whole population 80 may be taken as living on alluvium, 1,851 on London Clay with gravel, 750 on London Clay without gravel, and 180 on Lower London Tertiaries.

Phthisis death-rate for males - - -	226
,, ,, females - -	376.

Note that very few actual deaths would make great difference in these rates, so great a difference that no conclusion can be drawn from the figures. There was a good deal of ague during almost the whole of the period 1851–60, but towards the latter date improved tillage had got rid of much of this disease.

[23 ? ?] TUNBRIDGE, Kent. Acres, 46,179. Population, 34,271. Map 6.

Tunbridge.

This is a Wealden district, about two-thirds of which are clay and one-third sand. The north-eastern part is Weald Clay, mostly covered by thin loam and gravel, and intersected or bordered by streams with alluvium. This part has an average (pretty uniform) elevation of 100–150 feet, but the Weald Clay has a greater range of height in

particular places, 250 feet and 50 feet being the extremes. The larger part consists of sands and clays of the Hastings series, in irregular tracts and a good deal faulted, and rising to high ground (500 feet at Tunbridge Wells), the highest parts being often formed by outliers of Weald Clay, the lowest by Wadhurst Clay, and the intermediate slopes by Tunbridge Wells Sand. In this last sand a band of clay (Grinstead Clay) occurs, but not in quantity enough to affect materially the dryness of the sand.

The town of *Tunbridge Wells* is the largest in the district. It stands mainly upon the highest member of the Hastings Beds, to which it gives a name. A northern part of the town is on an outlier of Weald Clay at good elevation. There is a slope in the town of at least 70 feet. *Tunbridge* town is mainly on gravel over Weald Clay, but on the south there are houses on alluvium (often flooded), and a good many on gravel over Tunbridge Wells Sand and Wadhurst Clay. There is a slope of 40 to 50 feet in the town, but parts are flat, especially those to the south of the town. *Hadlow* is a large village on a flat of Weald Clay, covered by gravel and loam. There are other villages in the district, mostly on the Tunbridge Wells Sand at its junction with Wadhurst Clay, but they are of no importance by the side of the large places named. The southern part of the section described under Sevenoaks will give a good notion of this country also.

Of the population of Tunbridge district it is estimated that 200 live on alluvium, 8,312 on the thin gravels that cover the Weald Clay, 2,413 on uncovered Weald Clay, 21,946 on the more sandy parts of the Hastings Beds, and 1,400 on the clays of that formation.

Phthisis death-rate (registered) for males - 362
" " " females - 437.

Tunbridge is one of the districts of which the exact phthisis rate among residents is uncertain, on account of many consumptive invalids resorting to Tunbridge Wells. Not much less than half the consumption deaths of that town (in the brief and recent experience of a registrar who has supplied information) have been among visitor invalids. Allowance being made for the special circumstances of this town in the figures relating to the whole district, the figures 302 for the male death-rate and 364 for the female, are suggested as a fair approximation to the true rates among residents.

[27 ? ?] MEDWAY, Kent. Acres, 14,565. Population, 51,805.
Map 6.

A Chalk district, bordered on the north and west by the Medway and its narrow marshes. The general slope of the ground is in the main downwards from south to north and also from east to west. At the north-eastern edge of the district there is a little Tertiary sand. Medway.

Chatham and *Rochester* are by far the most important places of the district, which indeed contains little else than these towns and their suburbs. They lie on slopes of Chalk, rising to 200 feet in one direction and to 108 in another. These slopes are overlaid at *Brompton* (part of Chatham) by Thanet Sand. The Luton valley, which is covered by the houses of Chatham, has some gravel and brick-earth over its dry chalk bottom; but at the lowest parts of Rochester and Chatham, near the Medway, there is some alluvium over very low-lying chalk (the elevation of these parts above mid-level of the sea being only 18–20 feet), and here alone could there be any wetness of the superficial soil. *Gillingham* is on gravel over Thanet Beds.

Approximate number of residents on alluvium, 1,000; on Lower London Tertiaries, 5,000; on Chalk, 44,887; and there were at the census 918 persons on board vessels.

Phthisis death-rate (registered) for males - 607
" " " females - 353.

The male death-rate is greatly affected by the presence of a number of military and naval establishments in the district. The army and navy medical departments have kindly procured for this report several data which prove conclusively the great extent to which this disturbance goes; but as all the establishments of the district cannot be examined, it remains impossible to procure such corrections as would allow the true phthisis rate of ordinary male residents to be computed. The female phthisis death-rate has, therefore, been taken as the basis of an estimate of what the mean rate of the two sexes would be if the male population were not subject to disturbing influences; yet much uncertainty must remain as to the exactness of this estimate. At Chatham and Rochester there is little or no intermittent.

[31 ? ?] Romney Marsh, Kent. Acres, 46,785. Population, 5,708. Map 4, with memoir.

Romney Marsh.

Except a few houses at *West Hythe* that are on Weald Clay, all the district is marsh land and shingle, almost the whole is "below the level " of high water at spring tides, but the access of the sea is prevented by " tracts of shingle bordering the marsh, which are partly piled above " the level of high water, and by artificial walls which have been " erected where no barrier of shingle exists. The patches of blown " sand consists of irregular hillocks, generally less than 20 feet high." (Geol. Survey, memoir, p. 15.) The marsh, which is formed by peat and clay with occasional sand hillocks, is underlaid at a depth of 10–20 feet by loose sand of unknown thickness, which furnishes the water supply.

Lydd and *New Romney* are the only places of any size. Both are on shingle, along a former coast line bordered closely by marsh land, but the inhabited parts are all on shingle rising somewhat above the marsh level; many coastguard stations are on the shingle. *Dymchurch* is on the present coast, on the marsh, and lies very low. All the rest of the district is on the marsh land just described.

Of the whole population 2,849 may be taken as living on alluvium and 2,829 on shingle, and 30 on uncovered Weald Clay.

Phthisis death-rate for males - - 315
" " females - - 381.

The smallness of population forbids much reliance to be placed upon these figures.

In this district there used to be much intermittent, described as peculiar in a way that suggests its being frequently a complication of typhoid fever. There is less ague of late years, and what is seen is described as being more like than it was to the disease elsewhere met with.

[41 ? ?] Brighton, Sussex. Acres, 2,320. Population, 77,693. Map 9.

Brighton.

This district comprises the town within the municipal limits. Note that Hove is in Steyning district. The town is in its greatest part on slopes and in a valley of almost bare chalk; but some western parts are on an irregular accumulation (the elephant bed) of chalk-rubble and flints, quite as pervious as chalk itself; and along the valley there is a

Sheets of Map.	Districts in the order of their Phthisis Death-rate, as before shown.	Population, 1861.	Per-centage of Residents upon various Formations.													Remarks; chiefly as to what proportion of population on pervious and impervious parts of mixed formations.
			Alluvium.	Shingle.	Bagshot Beds.	Gravel on London Clay.	London Clay; no Gravel.	Lower London Tertiaries.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.	Gravels over Weald Clay.	Weald Clay; no Gravel.	Hastings Beds.	
1, 6	3. Dartford - -	32,316	8	—	—	—	0·	43β	49	—	—	—	—	—	—	β On pervious.
8	4. Epsom - -	22,409	—	—	—	11	13	38β	38	—	—	—	—	—	—	β Some on impervious.
3, 6	5. Milton - -	14,775	3	—	—	2	5	51β	39	—	—	—	—	—	—	β Mod. pervious.
6, 8	6. Godstone - -	9,642	—	—	—	—	—	—	23	1	0·	59γ	5	11	1	γ On pervious.
1, 6	7. North Aylesford -	19,121	1	—	—	—	—	18β	81	—	—	—	—	—	—	β Mainly on pervious.
3	9. Dover - -	31,575	6	25	—	—	—	—	69	—	—	—	—	—	—	
1, 6	10. Bromley - -	20,368	2	—	—	—	5	76β	17	—	—	—	—	—	—	β Mainly on pervious.
9	11. Steyning - -	24,053	1	—	—	—	—	—	80	7	0·	8γ	—	4	—	γ Part on impervious.
8	12. Chertsey - -	18,642	2	—	69α	29	—	—	—	—	—	—	—	—	—	α 56 on pervious; 13 on impervious.
6, 8	13. Croydon - -	46,474	0·	—	—	35	26	21β	18	—	—	—	—	—	—	β On pervious and impervious; artificially dried.
5, 6	15. Cranbrook - -	13,412	—	—	—	—	—	—	—	—	—	—	1	6	93δ	δ 84 on pervious; 9 on impervious.
7	16. Richmond - -	18,802	—	—	—	94	6	—	—	—	—	—	—	—	—	
7, 8	17. Kingston - -	36,479	—	—	4α	79	17	—	—	—	—	—	—	—	—	α On pervious.

APPENDIX.

No. 5.

On the Distribution of Phthisis as affected by Dampness of Soil, by Dr. Buchanan.

Sheets of Map.	Districts in the order of their Phthisis Death-rate, as before shown.	Population, 1861.	Percentage of Residents upon various Formations.													Remarks; chiefly as to what proportion of population on pervious and impervious parts of mixed formations.
			Alluvium.	Shingle.	Bagshot Beds.	Gravel on London Clay.	London Clay; no Gravel.	Lower London Tertiaries.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.	Gravels over Weald Clay.	Weald Clay; no Gravel.	Hastings Beds.	
3, 4	18. Elham	26,925	1	—	—	—	—	—	15	—	10	65γ	—	9	—	γ 61 on pervious; 4 on impervious.
3	19. Blean	16,161	13	4	—	6	36	41β	—	—	—	—	—	—	—	β Mod. pervious.
3	20. Bridge	11,316	4	—	—	0·	—	33β	63	—	—	—	—	—	—	β Mostly on pervious.
1, 6	21. Gravesend	18,782	0·	—	—	—	—	21β	75	—	—	—	—	—	—	Others on shipboard; β on pervious and impervious.
5, 6, 8, 9	22. East Grinstead	14,097	—	—	—	—	—	—	—	—	—	—	—	12	88δ	δ 82 on pervious; 6 on impervious.
8	24. Reigate	20,109	—	—	—	—	0·	2	7	5	1	52γ	22	10	—	γ 47 on pervious; 5 on impervious.
5	25. Eastbourne	10,721	1	2	—	—	—	9β	47	30	—	0	—	1	10	β On pervious.
8, 9	26. Farnham	30,707	1	—	67α	—	10	—	1	0·	9	12γ	—	—	—	α Mainly on pervious; γ pervious.
8, 9	28. Hambledon	13,907	—	—	—	—	—	—	—	—	—	49γ	20	31	—	γ On pervious.
5	29. Battle	12,680	—	—	—	—	—	—	—	—	—	—	—	—	100δ	δ 80 on pervious; 20 on impervious.
3	30. Canterbury	16,643	10	—	—	—	—	18β	72	—	—	—	—	—	—	β On pervious.
3, 6	32. Hollingbourn	13,584	—	—	—	—	—	—	32	—	9	37γ	4	18	—	γ On pervious.
6	33. Malling	21,447	0·	—	—	—	—	—	13	—	8	62γ	10	7	—	γ On pervious.
3, 4	34. East Ashford	12,286	2	—	—	—	—	1	30	—	20	25γ	—	20	2	γ 20 on pervious; 5 on impervious.
6	35. Sevenoaks	22,039	0·	—	—	—	—	—	8	2	4	47γ	5	17	17δ	γ On pervious. δ 12 on pervious; 5 on impervious.

Sheets of Map.	Districts in the order of their Phthisis Death-rate, as before shown.	Population, 1861.	Per-centage of Residents upon various Formations.													Remarks; chiefly as to what proportion of population on pervious and impervious parts of mixed formations.
			Alluvium.	Shingle.	Bagshot Beds.	Gravel on London Clay.	London Clay; no Gravel.	Lower London Tertiaries.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.	Gravels over Weald Clay.	Weald Clay; no Gravel.	Hastings Beds.	
8	36. Guildford	29,330	1	—	19α	7	9	5β	28	0·	0·	30γ	1	0·	—	α 15 on pervious; 4 on impervious. β On impervious. γ On pervious.
8, 9	37. Farnborough	14,318	1	—	60α	—	9	0·	—	—	1	29β	—	—	—	α Mainly pervious. β Pervious.
3	38. Eastry	25,900	2	21	—	—	—	27β	50	—	—	—	—	—	—	β Mainly pervious.
3	39. Faversham	18,867	2	—	—	—	3	31β	64	—	—	—	—	—	—	β Mainly pervious.
4, 5	40. Rye	11,927	3	1	—	—	—	—	—	—	—	—	—	—	96δ	δ 79 on pervious; 17 on impervious.
6	42. Maidstone	38,670	1	—	—	—	—	—	—	—	—	43γ	45	11	—	γ Pervious.
5, 9	43. Cuckfield	17,163	—	—	—	—	—	—	3	2	0·	17γ	—	25	53δ	γ 16 on pervious; 1 on impervious. δ 48 on pervious; 5 on impervious.
8	44. Dorking	12,445	—	—	—	—	1	2	8	0	1	56γ	1	31	—	γ Pervious.
5, 6	45. Uckfield	17,260	0·	—	—	—	—	—	—	—	—	—	—	1	99δ	δ 82 on pervious; 17 on impervious.
5	46. Hailsham	12,668	0·	—	—	—	—	—	—	—	0	1	—	34	65δ	δ 61 on pervious; 4 on impervious.
5, 6	47. Ticehurst	14,626	—	—	—	—	—	—	—	—	—	—	—	—	100δ	δ 67 on pervious; 33 on impervious.
9	48. Worthing	18,921	3	1	—	—	—	2	92	2	—	—	—	0·	—	—
3, 6	49. West Ashford	15,137	0·	—	—	—	—	—	8	0	3	50γ	5	34	—	γ 30 on pervious; 20 on impervious.
5, 9	50. Lewes	26,995	4	—	—	—	—	—	60	7	1	8γ	0·	10	10δ	γ Impervious. δ Pervious.

Sheets of Map.	Districts in the order of their Phthisis Death-rate, as before shown.	Population, 1861.	Per-centage of Residents upon various Formations.													Remarks: chiefly as to what proportion of population on pervious and impervious parts of mixed formations.
			Alluvium.	Shingle.	Bagshot Beds.	Gravel on London Clay.	London Clay; no Gravel.	Lower London Tertiaries.	Chalk.	Upper Greensand.	Gault.	Lower Greensand.	Gravels over Weald Clay.	Weald Clay; no Gravel.	Hastings Beds.	
3, 4, 5, 6	51. Tenterden - -	10,947	0·	—	—	—	—	—	—	—	—	—	—	29	71δ	δ 42 on pervious; 29 on impervious.
8, 9	52. Horsham - -	15,313	—	—	—	—	—	—	—	—	—	—	—	56	44δ	δ "Loamy sands."
9, 11	53. Westhamptnett -	14,811	1	—	10α	28	—	26β	32	1	2	0·	—	—	—	α Impervious. β Mainly on impervious.
9, 11	54. Midhurst - -	12,581	0·	—	—	—	—	—	3	14	2	53γ	—	28	—	γ 25 on pervious; 28 on impervious.
9	55. Thakeham - -	7,569	—	—	—	—	—	—	9	7	8	59γ	—	17	—	γ 45 on pervious; 14 on impervious.
8, 9	56. Petworth - -	9,397	—	—	—	—	—	—	—	—	—	30γ	—	70	—	γ Pervious.
9, 11	57. Westbourne - -	6,957	—	—	—	—	14	24β	62	—	—	—	—	—	—	β Mainly impervious.
9	58. Chichester - -	14,775	—	—	—	69	—	10β	2	7	5	7γ	—	—	—	β Mainly impervious; gravelled. γ Gravelled.
2, 3	1 ??. Sheppey - -	18,494	65	—	6α	0·	21	—	—	—	—	—	—	—	—	Others on shipboard. α Pervious.
5	2 ??. Hastings - -	26,631	—	—	—	—	—	—	—	—	—	—	—	—	100δ	δ 95 on pervious; 5 on impervious.
3	8 ??. Thanet - -	31,862	0·	—	—	—	—	4β	96	—	—	—	—	—	—	β Mod. pervious.
1, 6	14 ??. Hoo - - -	2,861	3	—	—	65	26	6β	—	—	—	—	—	—	—	β Pervious.
6	23 ??. Tunbridge -	34,271	1	—	—	—	—	—	—	—	—	—	24	7	68δ	δ 64 on pervious; 4 on impervious.
6	27 ??. Medway - -	51,805	2	—	—	—	—	10β	86	—	—	—	—	—	—	Others on shipboard. β Mod. pervious.
4	31 ??. Romney Marsh -	5,708	50	49	—	—	—	—	—	—	—	—	—	1	—	—
9	41 ??. Brighton - -	77,693	—	—	—	—	—	—	100	—	—	—	—	—	—	—

thickish bed of made earth, underlain by a flinty conglomerate known as Combe Rock. These are pervious, though less so than the chalk. At the lowest lying parts of the town the water-line is about 20 feet below the surface.

Phthisis death-rate for males	- - -	499
„ „ females	- - -	372.

These rates, but especially the male rate, are slightly raised by deaths in the Sussex County Hospital here; for practical purposes, however, this need not be considered. A more important disturbing influence (whose amount cannot at all be ascertained) is the use of Brighton as a place of residence for consumptive invalids; or the converse disuse of the town by residents who there become consumptive.

Summary view of connexion between soil and consumption.

IN the preceding table, so much of the geological account of each district is reproduced as relates to the formations on which people live, and the general perviousness or imperviousness of the soil may be learnt. The first impression from the table perhaps is that any of the great formations (with the exception of Weald Clay) may have on them a large share of the population of a district, and yet that district may have any position in respect of its phthisis mortality. But on looking into the list of districts (after a separate study of each) with special reference to the point suggested by last year's inquiry, the wetness or dryness of soil, it soon appears that the districts arranged in the order of the prevalence of consumption in them are also to a very great extent arranged in the order of the dryness or wetness of their soils.

It would be desirable, in proceeding to examine this point, to place the districts in a series according as each had fewer or more people living on wet or on dry soil. But it is impossible to do this on account of the want of universal comparability in respect of dryness and wetness between the soils of different formations, and even between soils made by the same formation in different geographical conditions. Thus the water-holding power of a soil is determined first by its degree of perviousness; and this, to begin with, is not the same throughout the whole extent of each bed, and still less can perviousness or imperviousness be taken as absolute terms to indicate that all pervious beds are exactly comparable together, or that one impervious bed is just as impervious as another. Secondly, the water-holding power of porous soils of equal permeability is determined in the main by different considerations than those which settle the water-holding powers of retentive soils of equal impermeability. In the former case, elevation, slope of subjacent beds, and other conditions indicating facility for water running away have chief weight in determining its wetness or dryness; in the latter case, of retentive soils, every consideration yields to the paramount one of surface slope. The difficulty of stating the precise order, as to dryness or wetness, of soils so various appears insuperable.

But though it is impossible to make the desired classification of all the districts, and although the evidence concerning the influence of soil is after all best shown by the detailed study of the particular districts, there are two ways in which the results of this inquiry may be summarized so as to present the facts in a prominent way. The one (A.) is to take groups of the districts in the order in which they stand for phthisis, and examine these groups as to the general perviousness or imperviousness of soil, trusting to other considerations of elevation, slope, &c.,

compensating each other within the group. This is, upon merely arithmetical grounds, an objectionable method, for all the facts concerning a particular district get overlaid by those affecting other districts; absolutely negative cases get concealed; and thus the groups cannot safely and profitably be contrasted. The other method (B.) is to select out of the 58 districts such as are most comparable with each other in regard of their position and geological structure, and to see how their phthisis is affected by the perviousness or imperviousness, elevation or lowness, slope or flatness in the members of such more limited series.

Summary obtained by grouping.

(A.) Upon the method of grouping districts it was attempted to make a rough grouping of soils, according as they were retentive or pervious, for comparison with the prevalence of phthisis in the group. The 50 districts whose true mortality from the disease is pretty well ascertained were divided into five groups, the first group A having the 10 districts with the smallest phthisis rates, group B having the next smallest, and so on to group E, the 10 worst districts for consumption. Then for each group of districts the people living on pervious soils and those living on retentive soils were reckoned up, and a small intermediate group was made of such soils whose conditions appeared to entitle them to a middle place.

The following table was thus obtained :—

In groups, each of 10 registration districts, having population as shown, the numbers of residents on various formations are as below :—	Group A. 219,516	Group B. 205,610	Group C. 186,941	Group D. 188,395	Group E. 134,482
Shingle and sea sand	8,000	900	—	5,800	—
Gravels over London Clay	8,036	63,526	2,200	—	14,330
Bagshot Beds, excluding tracts of Bracklesham	9,442 / 2,400	1,300	33,527	—	—
Lower London Tertiaries *	48,560	25,441	4,500	13,364	7,157
Chalk	96,057	36,326	33,033	44,143	27,838
Upper Greensand	1,620	—	580	850	5,180
Lower Greensand, excluding Sandgate Beds	25,010	14,210	54,619	26,745	17,086
Sandy members of the Hastings Beds	70	23,939	12,944	49,215	13,947
Per 1,000 of total population of the group living on these mostly pervious formations	**897**	**806**	**757**	**744**	**636**
London Clay, without gravel	4,903	24,905	7,090	580	1,000
Weald Clays, with gravels	500	4,489	7,040	17,630	730
Per 1,000 of total population of the group living on these formations of intermediately retentive character	**24**	**142**	**76**	**96**	**12**
Alluvium	6,525	3,084	2,880	2,070	1,370
Bracklesham Beds of Bagshot	2,400	—	? 1,000	—	1,570
Gault	2,763	240	9,105	120	2,435
Sandgate Beds of Lower Greensand	1,000	600	600	—	7,600
Weald Clays, without gravels	4,580	4,550	14,323	16,728	31,039
Clayey members of the Hastings Beds	—	2,100	3,600	11,150	3,200
Per 1,000 of total population of the group living on these retentive formations	**79**	**52**	**167**	**160**	**352**

* Lower London Tertiaries contain impervious beds, the population on which cannot be numerically separated; but as these are most of such beds in districts grouped E, the effect of separating them would apparently be to intensify the differences here shown between the groups.

Comparison of the five groups of districts shows a much larger proportion of residents on retentive soil in the 10 worst phthisis districts than in the 10 best, and if (by way of allowing for the intermediate character of the generally sloping London Clay and slight gravels on Weald Clay) we divide the middle class equally among pervious and retentive soils, we have the following series:—

Groups of Districts.	On Pervious Soils.	On retentive Soils.
A, with least phthisis -	- 909	91
B, with next least phthisis	- 877	123
C, middle as to phthisis	- 795	205
D, with still more phthisis	- 792	208
E, with most phthisis	- 642	358

But besides the arithmetical objections to which such a method as this is open, it is plain that, if retention of water in a soil be an influence upon consumption, a district has no advantage from mere perviousness of soil if it is so situated that its soil-water cannot get away. This very obvious consideration finds no expression on the foregoing tabular statements. In group A, for instance, the chalk is almost all high, while in group D low plains of gravel-covered chalk are reckoned under pervious soils, which might, as far as their water-holding faculty goes, as fitly find a place among the retentive formations.

Summary view by comparison of districts more or less resembling each other in geology.

But, leaving the method of grouping, and passing to the examination (B.) of more naturally comparable districts, the prevalence (α) *of phthisis upon pervious soils from which water can drain away, as compared with its prevalence upon retentive soils*, may first be investigated. The Wealden area of the south-eastern counties offers an excellent set of districts for the purpose of such a comparison—districts which differ from each other, too, in very few respects save in the matter of soil. The area in question comprises the Weald Clay, and the Hastings Beds of alternate sands and clays (page 61). Very different facilities of getting rid of water are presented by the elevated sands of the Hastings series and the flat plain of the Weald Clay; and, although there are no districts wholly of sand to contrast with others wholly of clay, the different effect of these soils respectively upon phthisis may be judged of by the different prevalence of the disease in districts formed by sands and clays in different proportions. Taking those districts where the majority of the people live in the Wealden area, and arranging them in the order of their consumptive mortality, the table on p. 104 shows the per-centage of people living on sandy soil and clay in each. Gravels over Weald Clay, being of intermediate importance, have been divided (in making the last columns) as if they were half sand and half clay.

Here the districts with less phthisis are seen to have more of their population on sands and less on clays, and those with more phthisis to have more population on clays and less on sands; the descending series of the per-centage numbers on sands and the ascending series of those on clays being wonderfully nearly regular for the districts arranged in the order of their consumption; so much is this the case, indeed, that they could not be expected to be more regular unless one should go the length of contending that phthisis was a disease influenced by no other circumstance than the one condition of soil.*

* It must be observed that the sands and clays of the Wealden area do not furnish the most thorough contrast that is possible in regard of water-retention, inasmuch as the sands are very fine and often clayey, and thus hold in water more than coarser sands or gravels. The displacement of Hambledon and Maidstone possibly may indicate that people living on Hythe Beds of the Lower Greensand are even better off, as regards consumption, than those on Hastings Sands; or else that the good qualities of gravels over Weald Clay have been under-estimated.

DISTRICTS the Majority of whose Population live on the Weald Country.

Order of District among the Fifty-eight Districts, in order of Phthisis Mortality.	Per-centage of Population resident on						Total on	
	Higher Beds, mostly Lower Greensand.		Weald Clay.		Hastings Beds.		Sands and Half Gravels over Weald Clay.	Clays and Half Gravel on Weald Clay.
	Sands of.	Clays of.	With Gravel.	Without.	Sands of.	Clays of.		
2.? Hastings	—	—	—	—	95	5	95	5
15. Cranbrook	—	—	1	6	82	9	82	18
22. East Grinstead	—	—	—	12	82	6	82	18
23.? Tunbridge	—	1	24	7	64	4	76	24
25. Uckfield	—	—	—	1	87	17	87	17
28. Hambledon	49	—	20	31	—	—	59	41
29. Battle	—	—	—	—	80	20	80	20
40. Rye	—	4	—	—	79	17	79	21
42. Maidstone	43	1	45	11	—	—	66	24
43. Cuckfield	21	1	—	25	48	5	69	31
46. Hailsham	—	—	—	34	61	4	61	38
47. Ticehurst	—	—	—	—	67	33	67	33
51. Tenterden	—	—	—	29	42	29	42	58
53. Horsham	—	—	—	56	44	—	44	56
56. Petworth	30	—	—	70	—	—	30	70

Comparison of various districts of pervious soils, as to elevation.

In the second place (β), it is evident that *within the limits of "pervious soils"* may be included very great range of wet and dry soils, according to *the elevation of the ground and the dip of subjacent impervious beds;* and this consideration appears to affect notably the prevalence of phthisis. Thus the "gravels over London Clay" form throughout the north of Surrey, tracts of somewhat elevated or inclined ground, beneath which the impervious clay has a notable slope, usually towards a stream. Districts in which a considerable part of the population live on such gravels are Epsom, Chertsey, Croydon, Hoo, Richmond, Kingston (with 11, 29, 35, 65, 94, and 79 per cent. respectively of the population of each upon these gravels), and these districts stand respectively 4th, 12th, 13th, 14th (?), 16th, 17th, among the 58 districts in the order of their mean phthisis rates (Table, pages 59–60). But at the southern part of Sussex the London Clay forms almost flat plains scarcely above high-water mark, and water is necessarily much held up in the gravels over such clay. Westhamptnett and Chichester are the only two districts in which much of the population (viz. 29 and 69 per cent. respectively) live on such low lying gravel over London Clay, and these two districts are 53rd and 58th on the list of the 58 districts, Chichester being in the worst position of all.

A like distribution of phthisis is observed in the several districts where much of the population lives upon the Lower London Tertiary formation. On the north of Kent and Surrey such districts are more or less high lying, and their beds are chiefly of sands and pebbles. Several of these districts have such small phthisis rates that they stand quite at the top of the list, Dartford, Epsom, Milton, and Bromley being respectively 3rd, 4th, 5th, and 10th among the 58 districts. Other Lower London Tertiary districts follow at no great distance down the list. Eastry and Faversham, with good part of their population on this formation, stand no higher than 38th and 39th on the list, although the beds are mostly pervious; but the Lower London Beds here do not, for

reasons of elevation and dip, readily get rid of their water. There are other districts into which the same formation enters that are among the worst of the districts for phthisis, but here (Westhamptnett 53rd, and Westbourne 57) the beds are low, flat, and waterlogged, and themselves are less pervious than in the northern tract of the Lower London Beds.

The Chalk affords another illustration. No soil is drier than chalk when it has a fair elevation ; it is so dry, indeed, that at its higher parts there are no streams, water cannot be reached by ordinary wells, and the people seek less elevated ground to supply themselves with the necessary element of water. In many districts the bulk of the population who live on Chalk occupy valleys with the water-line in the chalk not many feet below their houses ; and in the south of Sussex a still greater degree of wetness is reached, for large part of the area reckoned as Chalk is a flat plain on the sea level, covered by gravel, with the dip of the Chalk here and there inland. If, with this preface, reference be made to the description of various districts which have a majority of their population on Chalk, and to the table on pp. 59–60, it will be seen that the position, as regards consumption, of those districts will on the whole represent the order in which they would stand if they were arranged according to the better or worse elevation of the chalk area on which the population live. Thus, North Aylesford, Thanet, and Dover, which stand together seventh, eighth, and ninth among the 58 districts, have their inhabited chalk areas far more elevated, and their water better carried off than Worthing, Lewes, and Westbourne, which are respectively 48th, 50th, and 57th on the list. And if the intermediate chalk districts be compared, then it is still found that they range themselves in much the same order in regard of consumption and in regard of the high or low situation in which their population lives. It is indeed difficult to say with exactness, in the absence of more minute local details, what the precise degree of dryness of a chalk district is, and still less certainly can this be stated for particular spots where masses of population come together ; but the general connexion between small consumption and elevation of the chalk area is not to be mistaken, the only prominent exception being in the case of Brighton, about the true place of which in the series there is confessedly no accurate information.

Again, another illustration of the effect of elevation of porous soils may be found in a comparison of the several districts where the population live mainly upon Lower Greensand. Constructing for this formation a somewhat similar table to that relating to the Weald, and taking the per-centage of population living on pervious and retentive soils, we get a series agreeing with that of the Wealden table in showing generally a larger proportion of inhabited retentive soil, where the people suffer a greater consumption mortality. But there will be found on this table (besides the formerly observed irregularity of Hambledon, page 103, and note), a notable misplacement of Thakeham, in the series of figures that indicate the per-centage on pervious and impervious soil respectively. Now, the whole southern tract of Lower Greensand on which Midhurst and Thakeham are situated lies low, forming quite a different ground from the hills of the same formation on the north ; but incomparably the worst district for wetness of soil is Thakeham, where most of the Lower Greensand Beds are pervious, but where they form a low flat plain, through which runs a stream bordered by broad flats of alluvium.

The only suggestion of an exception to the rule that flat low-lying sands and gravels have a larger amount of consumption than those whose elevation and slope allow of water being got rid of, is in the case of those districts which have a good many houses built upon shingle. Dover is one of these, a quarter of the district population living in the lower

DISTRICTS where half or more of the Population live on Lower Greensand.

	Per-centage of Population resident on				Total on	
	Lower Greensand.		Other Formations.*			
	Pervious Beds.	Impervious Beds.	Pervious.	Impervious.	Pervious.	Impervious.
7. Godstone	59	—	28	13	87	13
18. Elham	61	4	15	20	76	24
24. Reigate	48	5	25	22	73	27
28. Hambledon	49	—	10	41	59	41
32. Malling	62	—	18	20	80	20
35. Sevenoaks	47	—	13	40	60	40
44. Dorking	56	—	12	32	68	32
49. West Ashford	30	20	11	39	41	59
54. Midhurst	25	28	17	30	42	58
55. Thakeham	45	14	16	25	61	39

* Weald Clay, covered by gravel, being equally divided between these two columns, as in former tables.

parts of Dover town, in such houses. Dover district stands no lower than ninth in the list of the 58 districts, and Dover town, even before its sanitary improvements, had a very small death-rate from consumption. Now, though much of the town and all the rest of the district is upon chalk and rubble, well placed as regards dryness, it appears certain that neither the district nor the town would have a good character for consumption if the saturation of the shingle was of material evil influence.—Again, the district of Romney Marsh is as low lying and as wet as any of the 58 districts, but its place on the list is probably not farther down than 31. Half of Romney population live on shingle, the other half on a sort of estuary alluvium.—Eastry is the third district that has any considerable part of its population on shingle, notably the town of Deal. This district stands 38th in the order of its phthisis, below Romney Marsh, but then there are in Eastry other low-lying places not on the sea face, which would be expected to resemble in their phthisis rates some of the low-lying chalk and tertiary districts that have been shown to suffer considerably from the disease. Upon the whole, then, it appears probable that low pervious beds saturated by sea water have not so high a death-rate from consumption as those saturated by other water.*

Comparison between various districts of impervous soils.

Next (γ), *as to the impervious formations* that have been investigated in the three counties. The various clays of the Hastings series and the Sandgate Beds have had their influence sufficiently demonstrated in the two tables that have dealt with the distribution of phthisis in the Wealden and in the Lower Greensand districts respectively. Of the clayey Bracklesham Beds of the Bagshot Sands little has to be said, except that they are most represented in the district of Westhamptnett, which in its phthisis rate stands far below any other of the Bagshot Sand districts.

* At first sight indeed it does appear from the experience of Dover that getting rid of the subsoil water from the shingle has operated to reduce consumption, and it would therefore seem that the sea water had its degree of deleterious influence on the disease. But the drainage operations of Dover had certainly far more effect in removing spring water from the subsoil than in altering the saturation of the shingle by the sea. (9th report of Med. Off. p. 132.)

There remain the two widely distributed impervious formations, London Clay and Weald Clay, and some consideration must also be given to the alluvial deposit of river sides and estuaries.

London Clay and Weald Clay differ very importantly from each other (pp. 62–64), in three chief respects—(1.) London Clay in its main extent through the three counties forms long slopes and notable hills; Weald Clay forms sometimes gently undulating but for the most part flat level ground. (2.) London Clay over large tracts is covered by beds of gravel reaching to many feet in thickness; Weald Clay has only very local gravels disposed in undulations of the clay, and rarely at all thick. (3.) Weald Clay is always bounded immediately to the north and south by higher ground, so that other beds drain more or less into its area; London Clay forms a more open country, and the direction of drainage from other beds is generally away from it. All these considerations show that the London Clay has commonly a much less degree of wetness than the Weald Clay.*

The difference between the two formations in respect of their phthisis mortality is unmistakeable. Firstly when it is covered by gravel, London Clay stands, as has been shown, among the best of the formations, except when its low lying flat position in Sussex brings it into physical conditions closely comparable with the habitual condition of Weald Clay. Of Weald Clay when covered by its local gravels it can only be said that it has not, so far as can be judged, so extremely high a death-rate from phthisis among the residents on it as where it has no gravel.

Comparison of the two formations when uncovered by any gravel brings out their difference in respect of phthisis quite as positively. On reference to the descriptions of the districts and to the table, it does appear that much uncovered London Clay in a district places certain localities (*e.g.* Croydon No. 13, Kingston No. 18, Blean No. 19), in a worse position than others, where this clay is covered by gravels or the soil is otherwise pervious, and this happens even though the ground should not be (as it is at Westbourne) low and flat. But on the whole it appears that there may be in a district a notable proportion of uncovered London Clay, forming high and sloping ground (as in the case of Epsom and the districts just quoted), without that district experiencing a very serious consumption death-rate. But of the Weald Clay, the evil effect upon phthisis was already conspicuous upon the first table that showed the connexion between consumption and soil in the 58 districts (page 102); and the next table, in which the Wealden area was particularly examined (page 104), brought out the relation between this formation and phthisis into even stronger relief. Of districts that have a third of their population on ungravelled Weald Clay, the best in regard of phthisis stands no higher than 42nd on the list. Only London Clay, when exceptionally placed in the same fashion as Weald Clay, or flat plains of gravel lying on the sea level and saturated with wet, make their appearance along with Weald Clay districts in the last-named 10 places on the general list where the consumption death-rate is most excessive.†

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* Weald means Wood, and this country used to furnish much timber to Portsmouth dockyard. It is on record that after a wet season the transit of timber from Kent to Hampshire has taken two years to effect, owing to the impassable character of the roads through the Weald.

† The observation may now be added that of such districts as stand high on the phthisis list having 10 per cent. or so of their inhabitants on Weald Clay, many are models of dry soils in their other parts, and from that circumstance might now be expected to rank somewhat higher than they can rank with the inclusion of Weald Clay.

Apparent exception in case of alluvium.

As regards alluvium, it bears in most districts but a small proportion to the whole area, and the residents on it bears a still smaller proportion to the entire population of each. Moreover, the presence of alluvium generally indicates that some other parts of the district lie flat and low. Hence it is difficult to assign a value to this retentive formation in respect of its influence on phthisis. There are two districts, however, Sheppey and Romney Marsh, in the one of which half, and in the other more than half the people live on low flat clayey alluvial plains, the other half of the population of Romney living on shingle. Both these districts exhibit death-rates from phthisis different from what the general conclusions of this report would have led us to expect. They are both indeed districts of which the true death-rates can scarcely be affirmed and the precise place of which in relation to other districts is doubtful, but there is no doubt that Romney Marsh is not far below the middle and that Sheppey is somewhere near the head of the list in the order of the 58 districts, whereas other districts that form low wet plains are together at the bottom of the list, or are met with in a better position only as higher and dryer ground enters into their composition. The exceptional behaviour of these two districts in regard of their phthisis must either have some exceptional reason or it must be confessed that they seriously disturb the chief conclusions that have appeared to be gained. Now, in two respects these districts of Sheppey and Romney Marsh actually are different from other low flat places in the three counties, and in either of these respects an explanation may be sought of their exceptional immunity (absolute or comparative) from phthisis. Firstly, the suggestion may be made these two are the very districts where there is the most ague, and the old belief in the exclusion of phthisis by ague may be a truth. To this, however, it must be answered—(1) that proof of the belief has not been satisfactorily given, by the exclusion on one side and on the other of other conditions influencing the occurrence of each disease, and that much evidence has been brought forward in support of the contrary opinion; (2) that in some of the other districts examined there has been a good deal of ague, not as much as in Sheppey or Romney, but still a good deal, and certainly as late as 1859. But these districts, Faversham, Rye, Maidstone, and Lewes,* stand indifferently or badly among other districts in the amount of their consumption, being respectively 39, 40, 42, and 50 among the 58. (3) That at Sheerness, the principal town of Sheppey, built wholly on alluvium below high-water mark, there is not so much ague as in the higher lying parts of the district, Eastchurch and Minster, and there is also (on the testimony of Dr. Swales, of Sheerness) distinctly less consumption produced in the town than in the villages of Sheppey beyond Sheerness. Probably, then, the suggestion that phthisis is comparatively little prevalent in Sheppey and Romney, on account of the agues there, may be put aside with the remark that these districts furnish excellent examples of the sort of places concerning which the statements has been made. But another suggestion may be hazarded in favour of which is the analogy of the towns upon shingle already discussed. In the same way as towns built on low lying pervious soil stand exceptionally well in their amount of phthisis if their soil be

* Milton and Hoo (so far as any inference can be drawn from the small population of Hoo) are other districts which have intermittents, and yet go along with Sheppey and Romney in not having very much phthisis. Both, however, range themselves pretty intelligibly when classified by their geological characters. But yet they may require some such consideration as is being advanced for Sheppey and Romney to account for their being better than some other districts in regard of their consumption rate.

saturated by sea water, so may not places situated like Sheerness and Romney, on sites which are scarcely more of land than sea, have an exceptional immunity from phthisis among those districts that have flat retentive soils? No other of the south-eastern districts at all resembles these two in the degree to which their soil has been gained and is (more or less artificially) withheld from the sea.* Without venturing to give an answer to this question, it may be allowed that there is enough of special character in the conditions of Sheppey and Romney districts to separate them from the numerous low-lying districts, upon the uniform experience of which it is stated that low-lying retentive soils have high mortality from phthisis.

The following general conclusions then result from the present inquiry:—

Summary of conclusions.

(1.) Within the counties of Surrey, Kent and Sussex there is, broadly speaking, less phthisis among populations living on pervious soils than among populations living on impervious soils.

(2.) Within the same counties, there is less phthisis among populations living on high-lying pervious soils than among populations living on low-lying pervious soils.

(3.) Within the same counties, there is less phthisis among populations living on sloping impervious soils than among populations living on flat impervious soils.

(4.) The connexion between soil and phthisis has been established in this inquiry—

(*a*) by the existence of general agreement in phthisis mortality between districts that have common geological and topographical features, of a nature to affect the water-holding quality of the soil;

(*b*) by the existence of general disagreement between districts that are differently circumstanced in regard of such features; and

(*c*) by the discovery of pretty regular concomitancy in the fluctuation of the two conditions, from much phthisis with much wetness of soil to little phthisis with little wetness of soil.

But the connexion between wet soil and phthisis came out last year in another way, which must here be recalled—

(*d*) by the observation that phthisis had been greatly reduced in towns where the water of the soil had been artificially removed, and that it had not been reduced in other towns where the soil had not been dried.

(5.) The whole of the foregoing conclusions combine into one—which may now be affirmed generally, and not only of particular districts—that WETNESS OF SOIL IS A CAUSE OF PHTHISIS TO THE POPULATION LIVING UPON IT.

(6.) No other circumstance can be detected, after careful consideration of the materials accumulated during this year, that coincides on any large scale with the greater or less prevalence of phthisis, except the one condition of soil.

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* Even the towns of Rye district on the borders of Romney Marsh are on a rise that takes them comparatively away from the sea. Sea-atmosphere alone does not appear to influence the prevalence of phthisis; the districts at the south of Sussex that have been repeatedly cited as the worst in their phthisis rates are mostly on the coast, and, on the other hand, Hastings and Thanet, which stand extremely well, are on the coast likewise. It is possible that in the suggestion of the text there may be a clue to the cause of the discrepant evidence about phthisis and ague? Does a salt water marsh give to those who live on it a disposition to ague but not to phthisis? while a river marsh or flat soil in proximity to a salt marsh conduce to both ague and phthisis?

(7.) In this year's inquiry, and in last year's also, single apparent exceptions to the general law have been detected. They are probably not altogether errors of fact or observation, but are indications of some other law in the background that we are not yet able to announce.

Postscript.—The conclusions of this report had been drawn, and their agreement with observations of last year's report had been seen, when, at the end of 1867, my attention was directed by Dr. Gavin Milroy to the Seventh Annual Report of the Registrar-General for Scotland, in which (pp.xlvii–xlviii), he quotes "the conclusions which Dr. Bowditch " of Boston, U. S., has drawn from a very thorough inquiry into one " of the causes of consumption in Massachusetts." The Registrar General writes: " It must be remembered that consumption is much " more fatal in Massachusetts, and in the United States of America " generally, than in this country; and on investigation it was found " that the towns, villages, hamlets, and houses which were situated at " or near undrained localities, or were on heavy impermeable soils, or " on low lying ground, and whose sites were consequently kept damp, " had a very much larger number and proportion of cases of con- " sumption than towns, villages, hamlets, or houses which were situated " on dry or rocky ground, or on light porous soils where the redundant " moisture easily escaped. Let us see how such an explanation would " agree with the very different proportion of deaths from consumption " which occur in the eight principal towns of Scotland. Taking a five " years' average (1857 to 1861 inclusive), it is found that, supposing all " these towns are brought to an uniform population of 100,000 persons, " there died annually from consumption 206 persons in Leith, 298 in " Edinburgh, 310 in Perth, 332 in Aberdeen, 340 in Dundee, 383 in " Paisley, 399 in Glasgow, and 400 in Greenock. The fact is, that if " each town had been arranged in the order of comparative dryness of " its site, they would almost have arranged themselves in the above " position—Leith and Edinburgh the most free from consumption, and " also having the driest sites; Glasgow and Greenock the most ravaged " by that disease, and beyond all comparison situated on the dampest " sites. The above fact, then, with regard to the towns, corroborates, " in the most striking manner, the conclusions of Dr. Bowditch, and " should be a valuable help to the sanitary reformers, as to the very " important measures which it is their more especial province to carry " out. Dr. Bowditch's conclusions also are singularly borne out by the " remarkable freedom from consumption at the Cape of Good Hope and " South Africa generally, Egypt, etc., and the comparatively high mor- " tality from it in the moist climate of Great Britain; and while they " point out the cause, afford valuable indications as to the cure or relief " of those affected."

Until the end of my own inquiry, I was in complete ignorance of Dr. Bowditch's researches. I should not insist on this point, except for the purpose of giving to the conclusions which Dr. Bowditch and myself have obtained the additional weight that they deserve from having been arrived at by a second inquirer, wholly ignorant of and therefore unbiassed by the work of the first. Several efforts that I have made to obtain a copy of Dr. Bowditch's pamphlet have unfortunately failed, and I am therefore unable to give, as I had wished, an abstract of the observations which he brings to the support of his conclusion.

No. 6. *On the Communicability of Tubercle by Inoculation, by Dr. Sanderson.*

No. 6.—DR. SANDERSON'S REPORT on the COMMUNICABILITY of TUBERCLE by INOCULATION.

The investigations to which the following report relates, were undertaken in co-operation with the Medical Officer of the Privy Council for the purpose of testing the truth of certain statements recently made on high scientific authority, as to the effects of inoculating animals with morbid products derived from persons affected with tubercular disease, and of determining to what extent, and under what conditions, this or other allied diseases of man can be transmitted to the lower animals.

Scope of the inquiry.

The problems which appear to me to be comprised within the scope of such an inquiry may be stated as follows :—

1. Is it true that the inoculation of tuberculous matter produces in the lower animals morbid changes, so constant in their anatomical character and development that they may be regarded as constituting a disease? And if so, in what terms can it be defined?

2. In what respects do the morbid results produced by the inoculation of tubercle resemble or differ from other diseased conditions communicable by the same process, particularly pyæmia, glanders, and syphilis: and to what extent are they comparable with the effects produced by the introduction into the circulation of inert solid matter in a state of fine division?

PART I. INOCULATION OF TUBERCULOUS MATTER.

For the determination of the first question, experiments have been made on 53 guinea-pigs. Of these, 30 were inoculated directly with diseased material from tuberculous patients, and 23 with material taken from the diseased organs, or with the blood, of animals previously inoculated. Of the latter, 13 were inoculated directly from animals of the first series, which in their turn yielded material for the inoculation of the remainder. Of these animals some are still under observation, but a sufficient number have died of the effects of inoculation, or have been killed for anatomical purposes, to enable me to report fully on the structural characters and development of the lesions produced. The quantity of material used in each inoculation was extremely small. The mode of insertion employed will be described below.

Primary inoculations.

FIRST SERIES. INOCULATION OF HUMAN TUBERCLE.

Observation I. Inoculation of grey granulations of pia mater.

OBS. I., April 16th.—Three guinea-pigs were inoculated with tuberculous material from the pia mater of a patient who had died three days before in the hospital for sick children, under the care of Dr. West. The patient, a boy aged four years and seven months, had been admitted six days before his death with symptoms of tubercular meningitis, the disease having already existed three weeks. His health had been good until two months previously, when he had an attack of scarlatina, from which, however, he recovered, and remained well until the 25th of March, when a succession of convulsive seizures occurred, ushering in his fatal illness. The following were the results of the post-mortem examination :—On removing the calvarium and dura mater the convex surface of the hemispheres was seen to be moist, and the convolutions were flattened. The intervals between them, especially round the branches of the middle meningeal artery, were beset with granular deposit, which, however, was strictly limited to the sulci. The sectional surfaces of the brain were moist and pale, and the ventricles were distended with serum. The surfaces of the corpora striata

were roughened with minute granulations, and the septum lucidum was ruptured. On examining the base of the brain the pia mater covering the interpeduncular space was seen to be much thickened and hyperæmic. The thickening extended into the sylvian fissures, both of which were blocked up by exudation, and on opening up the right fissure, a mass of tuberculous matter as large as a filbert was exposed. All the other organs were carefully examined, but no trace of tubercle could be discovered.

Microscopical dissection.—On making sections of the mass of the right sylvian fissure it was found to be partly grey and semi-transparent, partly white and opaque. The grey parts consist of a transparent matrix, in which innumerable round or oval nucleated cells and nuclei are embedded. The diameter of each cell scarcely exceeds that of its nucleus. In some parts of the structure the nuclei, instead of being round or oval, present all intermediate forms between the spheroidal and those usually found in the connective tissue of the pia mater. The opaque white parts appear to consist of granular stroma, in which nuclei are still to be observed in greater or less abundance. Similar appearances present themselves in the thickened pia mater at the base of the brain. Not only here, but on the surfaces of the corpora striata, the vessels of the affected parts exhibited the usual changes. The multiplication of nuclei or nuclear cells had taken place in the sheaths of many of the capillary arteries to such an extent as to conceal their natural structure.

The three animals were inoculated from the tuberculous mass above described. The method employed consisted in passing a narrow-bladed scalpel under the skin, and then inserting the material into the wound with a pair of fine-pointed forceps.

No. 1. The animal was killed 56 days after inoculation. Morbid appearances were observed at the seat of insertion, in the lymphatic glands, in the spleen, liver, and lungs. The spleen was employed to inoculate three other animals. (See Obs. XI.)

No. 2. Killed 70 days after inoculation. The same organs were diseased. Three healthy animals were inoculated with morbid matter from the spleen, and three others with the blood. (See Obs. XII. and XIII.)

No. 3. Killed 93 days after inoculation. The lungs were healthy, the liver was scarcely at all diseased, but the spleen and lymphatic glands, as well as the subcutaneous cellular tissue at the seat of inoculation, exhibited the same appearances as in the other two animals.

Observation II. Inoculation with sputum of a patient affected with phthisis in the third stage.

Obs. II., May 2nd.—Four guinea-pigs were inoculated with sputum, collected three hours previously, of a patient affected with phthisis in the third stage, under the care of Dr. Quain, at Brompton Hospital. The patient died on the 16th of June, when the following appearances were noticed :—There were extensive and firm adhesions of both pleuræ. The right lung was for the most part crepitant, but beset with grey granulations, the smallest of which were semi-translucent. There was a small cavity near the apex, the base of the lung being hyperæmic and airless. The left lung was much contracted, of fibro-cartilaginous consistence, and perfectly airless. At its upper part was a large cavity containing much grumous fluid, and smaller cavities were scattered here and there throughout its substance. The pericardium was adherent by both its surfaces, and was much thickened. When stripped off the heart it left a surface roughened with shaggy lymph. With the exception of ulceration of the ileocæcal valve there were no important lesions of other organs.

The material used for inoculation was purulent and creamy sputum, here and there streaked with blood. It was found on microscopic examination to consist of pus cells, ropy mucus containing albuminous granules and oil globules, shreds of lung tissue, and sporules of fungi.

The animals were inoculated with an instrument devised for the purpose. It was similar to that subsequently used (see Obs. III.) but less perfect.

No. 4. Died 54 days after inoculation. The lymphatic glands, lungs, liver, and spleen were diseased. The condition of the subcutaneous cellular tissue was not noted either in this or the following case.

No. 5. Died 51 days after inoculation. All of the internal organs were diseased.

No. 6. Died 75 days after inoculation. The usual appearances were observed at the seat of insertion, in the lymphatic glands, and in the internal organs.

No. 7. Killed 77 days after inoculation. There were no morbid appearances.

Observation III. Inoculation of sputum of a patient affected with phthisis in the third stage.

OBS. III., May 10th.—Two guinea-pigs were inoculated with recent expectoration of a female patient, admitted into Brompton Hospital on the 9th of March, under the care of Dr. Quain. Death occurred on the 13th of May. The record of the post-mortem examination (at which I was present) was unfortunately not entered in the hospital register. At the time that the expectoration was collected the patient was in a state of extreme prostration, accompanied with the usual symptoms of the final stage of phthisis. The physical signs afforded evidence of extensive disintegration of the upper parts of both lungs, and of the existence of one or more large cavities at the apex of the left lung. This diagnosis was verified after death.

The sputum consisted of pus corpuscles similar in character to those above described. It contained fatty and albuminous granules, and various forms of fungus growth, viz., hyphaceous filaments, and spores of two varieties, one of which exhibited a necklace-like arrangement.

The instrument used for these and all subsequent inoculations consists of a steel canula, about three-fifths of a line in diameter, pointed at one end like the tube of a subcutaneous injection syringe, and fitted with a steel rod, which is of the same length and bevelled in the same manner as the canula. In using it, the material to be inoculated, if liquid, is drawn into the pointed end of the tube by pulling back the rod or piston for a line or two. If it is intended to employ solid matter, the instrument is easily charged by introducing the material into the same part of the tube with the aid of a pair of fine forceps. In inoculating, the point is passed under the skin to such a distance as to cover the whole of the bevelled part in the same manner as in hypodermic injection, and the material pushed out with the rod. In this way the insertion is accomplished with the utmost certainty, and with the least possible injury to the subcutaneous cellular tissue.

No. 8. Killed 69 days after inoculation. There was suppuration in the course of the wound, enlargement and softening of the subcutaneous lymphatic glands, and advanced disease of the spleen, liver, and lungs.

No. 9. Died 78 days after inoculation. The morbid appearances were similar to the last.

Observation IV. Inoculation of caseous

OBS. IV., May 14th.—Two guinea pigs were inoculated with caseous material from the lung of the patient whose sputum was employed in Obs. III., who died two days previously.

No. 10. Died 45 days after inoculation. Disease existed at the seat of inoculation, in the spleen, liver, and lungs.

No. 11. Killed 65 days after inoculation. The morbid appearances were of the same nature, but the lesions found in the internal organs were more advanced.

material from the lungs of the same patient.

Observation V. Inoculations of miliary tubercle of lung.

Obs. V., May 28th.—Two guinea-pigs were inoculated, one (No. 12) with miliary tubercle from the lung, the other (No. 13) with miliary granulations from the peritonæum of a patient who died of acute tuberculosis in Middlesex Hospital, under the care of Dr. Goodfellow. The morbid appearances were as follows :—Both pleuræ were studded with minute semi-transparent granulations, the right being partially adherent. Grey miliary granulations were disseminated abundantly throughout both lungs, especially the left, but *no deposits of old tubercle could be discovered.* The under surface of the diaphragm and the serous coverings of the liver and spleen were dotted with granulations, those on the liver having membranous shreds attached to them. The liver substance appeared normal to the naked eye, but on microscopic examination "numerous minute aggregations of nuclei, having all the characters of tubercle," (Dr. Cayley), were found to be disseminated through it. Several opaque yellow nodules existed in the kidneys, the size of which varied from that of a millet seed to that of a hemp seed. There were small tubercular ulcers in the ileum, particularly in Peyer's patches, and the corresponding mesenteric glands were enlarged. The pia mater was injected and ædematous, and grey granulations were observed in the sylvian fissures. No other morbid appearances were detected.

No. 12. Died 31 days after inoculation. There was disease of the spleen, lungs, and liver. The lymphatic glands were also diseased, but the state of the wound was not noted.

No. 13. Died 45 days after inoculation. There was suppuration in the course of the wound, with enlargement and softening of the lymphatic glands; the internal organs exhibited the usual appearances.

Observation VI. Inoculation of caseous material from the lung of a patient affected with phthisis.

Obs. VI., May 28th.—Three small guinea-pigs were inoculated with infiltrated tubercle (caseous pneumonia) from the right lung of a female patient, aged 22, who died in Brompton Hospital the day before, under the care of Dr. Pollock. The condition of the diseased organs was as follows:—There were firm adhesions of the right pleura towards the apex, the rest of the pleural cavity containing coagulated blood, the origin of which was not ascertained. The right lung, with the exception of the posterior part of the lower lobe was densely infiltrated with solid tuberculous material. Near the apex there was a small cavity containing grumous fluid. The left pleura, which was slightly adherent, and the left lung was free from tubercle excepting at its apex, where there were a few small masses of consolidation. The other organs were healthy.

No. 14. Died 44 days after inoculation.

No. 15. Killed 54 days after inoculation.

No. 16. Killed 54 days after inoculation.

In all these animals the lymphatic glands, spleen, lungs, and liver were diseased. In No. 16 there were also nodular deposits in one of the kidneys. The inoculation wounds and the surrounding subcutaneous cellular tissue exhibited the usual appearances.

Observation VII. Inoculation of infiltrated tubercle of

Obs. VII., May 28th.—A guinea-pig was inoculated with material from marginal infiltration surrounding an intestinal ulcer in a female patient, aged 43, who died the day before in Brompton Hospital, under the care of Dr. Alison. The condition of the organs was as follows :—

The upper two-thirds of the left lung were infiltrated with grey deposit, the lower third containing air. The right pleura was firmly adherent, and the right lung was scattered with tuberculous masses. There were numerous ulcers of irregular form with thickened margins in the cæcum and ascending colon; rounded ulcers of similar character were met with at intervals towards the lower end of the ileum, some of which were as large as a florin. The other organs presented no lesions of importance.

No. 17. Killed 54 days after inoculation. The pathological appearances observed at the seat of inoculation, in the lymphatic glands, and in the internal organs were of the same kind as in the other experiments.

mucous membrane of ileum.

Obs. VIII., May 31st.—Three guinea-pigs were inoculated with miliary tubercle from the lung of a female patient, aged 27, who died at the Brompton Hospital three days previously, under the care of Dr. Pollock, of acute tuberculosis complicated with cerebral symptoms. Both lungs were scattered with miliary nodules of grey semi-transparent material; the pleura was in some parts natural, in others more or less opaque as if infiltrated with opalescent deposit, while in others it was studded with numerous granulations, some of which were exceedingly minute, others as large as hemp seeds. These on microscopic examination were found to consist of nuclei of various forms and sizes, which appeared to be grouped in greatest abundance in the neighbourhood of minute arteries. The pia mater exhibited no appearances of disease which could be recognised by the naked eye, but on microscopic examination it was found that there was multiplication of nuclei in the sheaths of the capillary arteries.

Observation VIII. Inoculation with miliary tubercle of lun

No. 18. Died 98 days after inoculation.
No. 19. Died 28 days after inoculation.
No. 20. Died 56 days after inoculation.

In each case the lymphatic glands, liver, and spleen were diseased; the lungs were diseased in No. 18, but were free from disease in Nos. 19 and 20.

Obs. IX. June 10th.—Two guinea-pigs were inoculated from tuberculous deposit in the great omentum of a patient who died in Brompton Hospital, under the care of Dr. Alison. In this case the most important post-mortem appearances were as follows:—Both pleuræ were firmly adherent; grey, elevated miliary granulations were disseminated throughout the whole of both lungs. The bronchial tubes were dilated and the bronchial mucous membrane thickened and injected. The bronchial glands were enlarged and indurated. The heart was firmly adherent to the pericardium, the aortic valve atheromatous and incompetent. The peritoneal cavity contained about two pints of greenish fluid. The mesentery was scattered with grey granulations. The omentum was thickened and indurated, and formed a hard mass, which during life had been felt through the abdominal wall. The spleen was enormously enlarged and hyperæmic, and contained masses of cheesy deposit. In the cortical substance of the kidney there were also several nodules of cheesy material. The mesenteric glands were much enlarged and indurated.

Observation IX. Inoculatic of infiltrated tubercle of great omentu

No. 21. Died 108 days after inoculation.

No. 22. Died 93 days after inoculation. With the exception that the morbid processes were more advanced in all the organs, the appearances corresponded with those previously observed.

Summary of Pathological Appearances observed in the above 22 Animals.

1. *Appearances observed in the wound produced by inoculation, and in the surrounding subcutaneous areolar tissue.*

Induration and suppuration in and around inoculation wound. Secondary subcutaneous abscesses.

In the animals first dissected my attention was not drawn to the importance of these appearances, so that the following statement is based on the dissection of nine animals only, viz., Nos. 3, 8, 11, 15, 16, 17, 18, 20, and 21. The morbid alterations observed consisted in (1) induration and thickening of the subcutaneous connective tissue; (2) formation of pus in the track of the wound; (3) formation of secondary subcutaneous abscesses in its neighbourhood; and (4) formation of bands of induration, analogous to farcy cords, between one abscess and others in its neighbourhood. In each of the nine animals referred to there was evidence that suppuration had taken place in the track of the wound; in all excepting one (No. 3) an abscess actually existed at the time of the dissection; in the exceptional case there was an open wound from which pus had escaped. The induration varied in extent; it was usually considerable, forming a hard ridge by which the course of the inoculating instrument could be traced before the skin was removed. In five of the animals numerous abscesses were found in the neighbourhood of the wound. In the four remaining, although there were no abscesses, there was much thickening and condensation of the subcutaneous tissue, which often proceeded to a considerable distance from the seat of the inoculation.

Minute anatomy of subcutaneous lesions.

Microscopical dissection.—The pus found in the primary traumatic abscess, as well as that which occupied the secondary abscesses in its neighbourhood varied in character according to the time that the abscess had existed; it never possessed either the fluidity or the characteristic yellow colour of normal human pus, its consistence varying from that of cream to that of cream cheese, which it also resembled in colour. Under the microscope it exhibited the following elements:—

In recently formed abscesses the majority of the corpuscles presented characters which do not appear to me to be distinguishable from those of normal human pus. These corpuscles measured from $\frac{1}{2500}$ to $\frac{1}{2000}$ of an inch in diameter, and exhibited when treated with very dilute acetic acid from two to four highly refractive granules, forming a central nucleus. Along with these were always observed other corpuscles of less uniformly spheroidal form, which resembled conglomerates, and usually contained a greater or less number of fat granules. These were much larger than the ordinary pus corpuscles, their diameter being from $\frac{1}{1200}$ to $\frac{1}{800}$ of an inch. In the older abscesses, that is those in which the pus had become cheesy, a marked difference was observed in the character of the corpuscles, and particularly in their conduct when acted upon by weak acetic acid. This reagent was found to have lost its power of resolving the corpuscles into a bifid, trifid, or quadrifid nucleus enclosed in a zone of transparent substance; in short, the corpuscle was comparatively little altered by the acid, and retained a distinctly globular form. The larger glomeruli were found in much greater numbers in the caseous than in the creamy abscesses, and in some instances appeared to be the only corpuscular elements. (Plate I., fig. 7.)

The structural character of the connective tissue indurations was observed (1) in the cords of induration, connecting one abscess with another, and (2) in the walls of the abscesses. The cords were found to consist of a dense fibrillated stroma, in which the direction of fibrillation was parallel to the axis of the cord. This stroma was not in the slightest degree wavy, and when fine sections of it were made

in the direction of fibrillation it was found to be studded with innumerable staff-shaped nuclei, all of which assumed the same direction as that of the fibrillation. On the most careful examination of transverse sections no trace could be discovered of any vessels larger than $\frac{1}{500}$ of an inch, so that it appears to me impossible to regard these cords as thickened lymphatics. It was further noticed that around the capillary arteries there were accumulations of nuclei which differed from the ordinary staff-shaped nuclei of the tissue in being fusiform or spheroidal. In addition to this there were nests of corpuscles which could not be distinguished from the pus corpuscles of the neighbouring abscesses. Is it possible that these were pus corpuscles in the act of migration, and that the growth of connective tissue which constitutes the cord is the result of the irritation produced by them in their passage?

In making sections of walls of abscesses it was found that they always presented the same structure, viz., that they invariably consisted of condensed connective tissue, having the same character as that which forms the cords of induration. This tissue was continuous, externally, with the normal subcutaneous tissue. Internally, the abscess wall was lined by a layer of pulpy substance. This material (so called pyogenic membrane) was found, when examined separately, to consist of spheroidal cells* embedded in the meshes of a reticulated transparent stroma; when examined in sections made perpendicularly to the abscess wall it could be satisfactorily made out that this stroma was continuous with that of the dense fibrillated connective tissue on which the pyogenic membrane rested. (Plate I., fig. 4.) Appearances seemed also to justify the conclusion that the crowded, round, corpuscles of the pyogenic pulp, were homologous with the staff-shaped nuclei of the denser layers which surround it, but I was not able to satisfy myself of the existence of transitional forms. Well characterized capillary blood vessels were seen in the fibrillated layer, and channels containing blood corpuscles could be distinguished at all events up to the edge of the pyogenic pulp. In the areolar tissue, and among the muscular fibres of the panniculus near the abscesses, nests of spheroidal or spindle-shaped corpuscles were everywhere met with.

2. *Appearances observed in the Subcutaneous Lymphatic Glands.*

Enlargement, induration, caseous degeneration, softening, and suppuration of the subcutaneous lymphatic glands.

In all the animals the subcutaneous lymphatic glands were more or less diseased, the changes consisting in enlargement (hyperplasia), induration, and caseous degeneration; this last resulting either in softening or in the formation of cretaceous concretions. In every instance those glands were most affected which were in the neighbourhood of the inoculation wound. As therefore the insertion was usually made in the shoulder, the axillary glands, as might be readily anticipated, were the principal seat of disease. So constantly indeed was this the case, that it could always be discovered whether an animal was diseased or not by pressing the finger in the axilla. In the healthy guinea-pig two glands can be distinguished in the axillary region as being much larger than the rest; one lies close to the axillary artery, where it crosses the shoulder joint; the other is situated near the posterior edge of the scapula in the angle between the triceps muscle and the teres maximus. The latter, which in the guinea-pig is more frequently diseased

* In employing the word "cells" I do not mean to imply a belief that the objects in question are vesicular.

than any other, will be hereafter referred to as the scapular gland. The other subcutaneous glands which are apt to be affected are those which lie on either side of the trachea (tracheal glands), and those near the sub-maxillary salivary glands (sub-maxillary glands). The inguinal glands are also occasionally diseased.

The enlargement of the glands was enormous. In the greater number of animals the scapular gland had attained 40 or 50 times its normal weight, and five or six times its natural length. Enlargement was never observed without other changes. The hypertrophied glands always exhibited in section, patches of white or yellowish opacity of the cortical substance, indicating the commencement of caseous degeneration. The condition of the glands, as of the subcutaneous areolar tissue, was carefully investigated in nine animals only. In three of these, Nos. 16, 17, and 20, there was hypertrophy, with induration and cheesy degeneration. In the six remaining animals the scapular gland on the same side as the inoculation wound was converted into an abscess containing creamy or cheesy pus, and in one of these animals, No. 21, the tracheal glands of the same side were in a similar condition. It was further observed, with reference to these nine guinea-pigs, that the three cases in which there was no suppuration of the glands, were precisely those in which there were no abscesses under the skin in the neigbourhood of the inoculation wound, so that there was reason to regard the softening of the lymphatic glands as dependent upon the same conditions as the dissemination of purulent foci in the subcutaneous tissue.* The structural characters of the lymphatic glands were not investigated microscopically, my attention having been directed principally to the internal lesions.

3. *Appearances observed in the Lungs.*

General nature of the lesions observed in the lungs.

Of the 21 guinea-pigs successfully inoculated the lungs were found free from disease in three only. In the rest the lesions observed consisted in the formation of nodules of grey induration, which were disseminated in 14 of the cases, partly disseminated, partly confluent in the rest. These changes were in two animals associated with adhesive pleurisy, viz., in Nos. 10 and 21.

Increase of weight.

In the healthy guinea-pig the lungs weigh about four grammes, that is about one-hundredth part of the weight of the body. When altered by adenoid deposits they often weigh as much as 15 grammes. In those cases in which the nodules are small and much disseminated the weight scarcely exceeds the normal. The increase of weight due to the new growth was most considerable in those in which the duration of life after inoculation was greatest; thus, in three animals which, when dissected, had been inoculated respectively 93, 98, and 108 days, the weights were severally 2·2 per cent., 3·7 per cent., and 4·9 per cent. of the weights of their bodies.

Disseminated nodules.

As has been stated, the new growth either assumed the form of disseminated nodules or pervaded the tissue of the lung to such an extent that considerable portions of the organ were consolidated. There was, however, evidently no essential difference between the two forms of lesion, for in those cases in which the induration was continuous in some parts, it was constantly observed that there were disseminated nodules in others, and that the material of which the nodules were composed was identical in all its characters with that which formed the larger masses. We

* This inference was confirmed by later experiments.

proceed to describe the nodular, which must be regarded as the primary form of the alteration.

The nodules, when examined with the naked eye or with a lens, present great uniformity of appearance. They are always found in much greater numbers under the pleura than in the parenchyma of the lung. The sub pleural surface of each nodule is slightly convex, so that it projects more or less above the general surface of the pleura, exhibiting itself as an iron-grey patch, which contrasts strongly with the pink white hue of the healthy lung tissue which surrounds it. When the nodules are small the whole sub-pleural surface is convex, but in the larger nodules the centre of the patch is somewhat depressed, so that the margin forms an irregular annular prominence. On cutting through a nodule at right angles to the pleural surface it often appears to form a blunt cone, of which that surface is the base. The colour of the nodules is sometimes pale grey, but much more frequently it is steel grey or slate coloured, especially towards its margin; and on section it exhibits a similar colour. The smaller nodules have the semi-transparent appearance which is recognized as a characteristic of miliary tubercle. In the larger ones the translucency is confined to the external parts, the centre being opaque, and of softer consistence than the rest. There are, as may readily be understood, great differences as regards size. In two of the animals they were all no larger than pin-heads, while in others the diameters varied from one-fiftieth to one-tenth of an inch. From their form and structural relations it is evident that they are interstitial new growths which do not displace the lung tissue, but are incorporated with it and form part of it. In order to satisfy one's self of this fact, all that is necessary is to examine those nodules which happen to lie near the sharp margins of the organ. It is then readily seen that the form which each nodule assumes is not its own, but that of the organ in which it grows, and that the space it occupies is often not greater than that which would have been occupied by the corresponding portion of lung in the natural state.

Form of the nodules.

Their colour, consistence, and semi-transparency.

Their size.

Their structural relations.

In most cases the nodules are very equally dispersed through the affected organs; exceptions occur in which one lobe is found to be more abundantly infiltrated with new material than the rest, but these appear to be accidental, all parts of the organ being apparently equally liable to become the seat of consolidation. In one of the animals I counted 63 separate sub-pleural nodules, which were disseminated with equal frequency over the whole of the surface of both lungs, while as regards several others it is noted that they were too numerous to be counted. Although, as has been already stated, the greater number are superficial, there are many which occupy central positions, and these, so far as I have been able to ascertain, are invariably found in the neighbourhood of bronchi. It was never observed that the deposits were surrounded by a zone of inflammation. Occasionally the lung tissue around their margins was slightly injected, but this appearance was neither constant nor definite; the adjoining lung tissue was in general perfectly healthy in structure and appearance. It has already been stated that, in those cases in which the whole of a lobe was converted into a mass of new deposit, the appearance and consistence of the material were evidently the same as of that which constituted the nodules, for often, as in No. 21, it could be distinctly seen that what resembled infiltration was produced by the mere grouping together of smaller masses; it must at the same time be admitted that the difference between the confluent and disseminated forms of lesion was not entirely one of degree, for sometimes it was noticed that the whole of one of the lobes was consolidated,

Their distribution.

Confluent induration.

as in No. 14, although in other parts of the lung the amount of new material was inconsiderable.

In every case in which the nodules had attained a considerable size their centres were found to be softened. In one animal, No. 8, this softening had proceeded to such a degree that some of the masses were converted into vomicæ containing creamy fluid.

Formation of vomicæ.

Microscopical characters of new growths.—In the microscopical examination of the morbid growths above described it was found that very little progress could be made unless the parts to be examined were first hardened by steeping them for several weeks in a solution containing one-quarter per cent. of chromic acid. The anatomical statements contained in the following paragraphs are founded entirely on the examination of sections of diseased lungs prepared in this way.

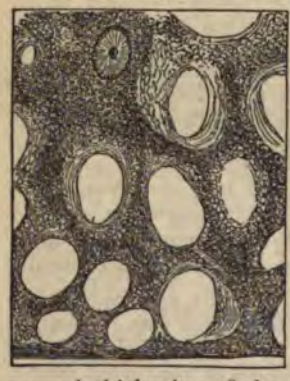
Minute anatomy of nodular indurations.

Peribronchial granulations consisting of adenoid tissue.

The disease always originates in the form of minute granulations, each of which, so far as I have been able to ascertain, is situated around, or in the immediate neighbourhood of a minute bronchiole, usually a bronchiole of three or four thousandths of an inch in diameter. One of these granulations is represented in the margin as seen with a low power. On more minute examination it is found to consist in the main of adenoid tissue, that is tissue resembling the pulp* of the cortical substance of a lymphatic gland; in other words, it is composed of nuclei, most of which appear to be free, although many of them are enclosed in "cells" little larger than themselves. These elements are embedded in a sponge-like stroma of extreme delicacy, in which no fibres or vascular channels can be distinguished. (Plate I. fig. 5.)

Origin of the new growth in the alveolar tissue of the lung.

The mode of origin of this tissue can only be judged of after its relation to the original structures of the lung has been determined. According to the best anatomists the walls of the pulmonary air cells (*i.e.* the pulmonary parenchyma) consists of an homogeneous transparent substance supported by a framework of elastic fibres, which in its turn serves to support the delicate epithelium of the air cells, while it includes the capillary network. (See plate I., fig. 3.) The examination of diseased lungs in the earliest stage of alteration seems to show that this homogeneous transparent substance which constitutes, so to speak, the interstitial stroma by which the other structural elements of the lung tissue (elastic trabeculæ, capillaries, epithelium,) are combined and held together, so as to form the delicate vesicular parenchyma of the healthy lung, is itself the matrix in which the new growth originates. How this transparent material is converted into adenoid tissue is a question not yet determined; all that can be seen is that it becomes loculated and that each vesicle contains one or more round bodies, which we designate as nuclei. At first the new growth is confined to the immediate neighbourhood of the bronchioles, from which it extends to the walls of the adjoining air cells; here it gives rise to a general thickening of the alveolar membrane, and consequent reduction of the capacity of each alveolus, and consolidation of the affected part.



Thickening of the alveolar walls.

* This pulp consists of masses or nests of cells, identical in their character with those described in the text, which are held together by a delicate network of transparent material, wherein capillary blood channels are contained, and fibres of extreme tenuity can be detected.—See Kölliker. Handbuch der Gewebelehre Menschen, 1867. P. 474.

As the process goes on, the bronchioles leading into the affected air cells probably become more or less obstructed, but do not undergo any appreciable change of structure, for in bronchial tubes which are surrounded on all sides by adenoid growth (see Plate I., fig. 5.) it may happen that there is no alteration either in the epithelium or in the tube wall; there is not the slightest sign of any inflammatory process affecting the bronchial mucous membrane. Eventually the diseased part becomes completely consolidated. This is brought about partly by the interstitial growth of cells in the substance of the alveolar walls, partly by the accumulation of epithelium in the alveolar cavity.* Whether by compression of the ultimate bronchus, or for other reasons, the epithelium collects in the vesicles, already reduced in size by the parietal thickening, so as to fill them up. In this way, as represented in the engraving (see Plate I., fig. 6), the diseased tissue is converted into a compact mass of cells, which to the unpractised or careless observer seem to have no special arrangement, and to be all of the same kind; if, however, they are more critically examined it is soon seen that there are two kinds of cellular elements, those of the one kind being at least twice as large as the other, and that the larger cells are grouped together in nests. These nests correspond to the cavities of alveoli, and are in fact clumps of alveolar epithelium. They are distinguishable from the others not merely by their size and well defined outline, but by the fact that most of them contain minute black pigment granules, which occupy their perinuclear spaces in considerable numbers. In comparing them with the alveolar epithelium of healthy lung it is easy to satisfy one's self that their characters are in the main unaltered.

Accumulation of epithelium in the alveolar cavities.

The next stage in the morbid process consists in the fatty degeneration of the whole mass. It is this disintegrative change which gives rise to the appearance of white or yellowish opacity always observed in the centres of the larger nodules. Both the epithelial cells and the parietal new tissue alike participate in it. The nuclei of the latter break up into smaller corpuscles of irregular form, while fat granules appear in great numbers round the nuclei of the epithelial cells, so that the whole is eventually converted into a granular detritus, in which the only well characterised forms are large cells so loaded with fat granules as to resemble conglomerates.

Fatty degeneration of the nodules.

If the changes referred to in the preceding observations have been correctly described they tend to show that, as regards the lungs, the effect of tuberculous inoculation is to give rise to the growth of new adenoid tissue in the interstitial substance which surrounds the smallest bronchioles and constitutes the alveolar walls, and that the change is neither inflammatory in itself nor accompanied by inflammation of the adjoining parts. The elastic fibrous framework of the lung seems to be entirely exempt from alteration, for the trabeculæ may be seen embedded in the new growth in a perfectly natural condition. The adventitia surrounding the arteries is also entirely unaltered, for the arteries are often to be seen in the very midst of consolidation, but separated from it by a distinct layer of unaltered connective tissue; so that it cannot for a moment be admitted that the change originates from the arterial sheaths. The nodular form and disseminated character of the growths seems to me to be partly accounted for by their relation to the terminal bronchioles, for it may be readily understood that a growth taking its start from a

Nature of the morbid process.

* The accumulation of epithelium (or whatever these larger corpuscles may be called) in alveolar cavities is only to be noticed at the marginal parts of each tubercle, the inner parts having no such corpuscles.

bronchiole and extending peripherally would be likely to assume the conical form of that part of the lung to which the bronchiole leads.

4. *Appearances observed in the Liver.*

Increase of weight.

The liver, which in the healthy guinea-pig constitutes from a twenty-fifth to a twentieth of the weight of the animal, often attains a weight two or three times as great under the influence of the tuberculous infection. In one of the animals (No. 22) the organ weighed 46 grammes, that is nine per cent. of its weight. The greatest relative weight was 12 per cent., in guinea-pig No. 16. The mean relative weight of the organ in 10 animals, in all of which the liver was markedly diseased, was 7·8 per cent.

General nature of the lesions observed.

Two kinds of lesion were noticed; the most obvious, and to the naked-eye observer the most common, consists in the conversion of certain abruptly defined portions of the hepatic tissue into a white opaque material. These isolated masses were met with in various parts of the organ, and varied almost indefinitely in size and form. In the advanced stages it sometimes happened that they were so large that a single mass fully occupied one of the three principal lobes into which the organ is divided; but more frequently they did not exceed a quarter of an inch in diameter. In form they are not altogether unlike the nodules of the lung. Some are completely concealed, but by far the greater number lie immediately under the capsule. Like the pulmonary nodules, they do not change the form of the organ in which they exist, for they are thoroughly incorporated with its tissue. In most of the animals they were found in greatest numbers in the neighbourhood of the sharp margin, and were less numerous in the middle or right lobe than in the left, to which it indeed several times happened that they were exclusively confined.

Islands.

These opaque masses, which I shall hereafter call *islands*, have several peculiarities obvious to the naked eye, which render it easy to distinguish them from all other disseminated deposits. When small they are of a dead white colour, and a firmer consistence than that of the organ itself of which they form part. As they enlarge, the colour changes from white to yellow, and the consistence diminishes, both alterations beginning from the centre; so that in all large islands there is a kernel of soft bile-stained pulp, and a cortex of firm material. Along with the softening there is diminution of bulk, for in the superficial islands the surface becomes so concave that the capsular membrane seems as if stretched over a cavity, hollowed out of the mass. It is further to be noticed that the margin of each island is commonly surrounded by a bright edging of hyperæmia, such as one sees in the human subject around splenic infarcts.

Interlobular growth of adenoid tissue

The above alteration is probably consequent on another less obvious change in surrounding parts of the liver. Both are in fact manifestations of the same process, in the development of which, the lesion now to be described stands first. The healthy liver of the guinea-pig is of an even red colour, resembling that of muscular fibre, but somewhat deeper. The elevations of surface which correspond to the acini can be made out on its external surface when the organ is so placed as to reflect a pencil of light to the eye, but there is no perceptible difference of colour between the lobules and the interlobular spaces. As soon, however, as the organ becomes diseased its size increases while its colour becomes paler. On more attentive examination the paleness is seen to be very unequally distributed, occurring here and there in patches of grey mottling, especially

in the neighbourhood of the islands, if any exist. On making sections of such a liver the mottling is even more apparent than on the natural surface. The grey parts obviously differ in appearance from the islands; while the islands are absolutely opaque the mottling is semi-transparent. To the practised eye the one conveys the idea of a living growing tissue, while the other suggests fatty degeneration or necrosis.

As the process advances, two important characters manifest themselves. First, the organ changes its form. This change is of such a kind as to remind one of the hobnail or cirrhotic liver of human pathological anatomy, a resemblance which, however, is only partial. Each lobe is seen to be divided by deep furrows extending in various directions across its under surface, into prominent nodosities, the general form and character of which may be judged of by the accompanying sketch. The second consists in the extension of the mottled appearance to the whole of the diseased and enlarged organ. When this has taken place it becomes possible, even with the naked eye, to satisfy one's self that the pale parts are interlobular, and that the less altered points correspond to acini.

Change of form of the organ which results from it.

Interlobular mottling of the natural and sectional surfaces.

Microscopical Dissection.—The microscopical examination of the liver in disease is beset with difficulties. My study of the changes above described is as yet incomplete. It is, however, sufficient to enable me to draw some important conclusions as to the relations with the other lesions observed.

Minute anatomy

The islands contain scarcely any elements foreign to the structure of the liver. Each consists in its unsoftened state of a certain number of acini in an anæmic condition. The softening is a process of retrogressive change. The tissue loses its vitality apparently from want of blood. The gland cells eventually undergo fatty degeneration, and become disintegrated; but, evidently, this is not the beginning of the change, for in islands of recent growth and inconsiderable extent the cells are in a natural condition.

of the islands;

The grey interlobular deposit consists of adenoid tissue. To investigate it, it is absolutely necessary to harden the organ in solution of chromic acid. A good general view of the distribution and arrangement of the new growth may be obtained by making a large and moderately thin section through the whole of a diseased lobe, so as to cut across the channels in which the duct and vessels are contained, and examining it in glycerine with a low power. It is then seen that the new material forms masses which are so arranged in relation to the bile ducts that each seems to be surrounded by a zone of transparency. In pursuing the investigation with a higher power it is not difficult to satisfy one's self, even in fresh sections, that this arrangement is not confined to the larger ducts, but extends to those smaller ramifications which are designated *ductus interlobulares*—ducts scarcely exceeding $\frac{1}{1000}$ of an inch in diameter, the cellular lining of which assumes transitional forms intermediate between epithelium and liver cells. In fine sections of hardened liver the following facts can be made out:—

of the interlobular growth.

The grey semi-transparent material consists of adenoid tissue, that is, of a delicate sponge of transparent connective substance, in the cavities of which minute cells or nuclei are lodged.* The diameters of these

* See Minute Anatomy of pulmonary lesions, p. 7.

cavities are seen on section to be about $\frac{1}{1500}$ of an inch. They communicate with each other in all directions, being bounded by membranous septa. The nuclei have a mean diameter of about $\frac{1}{4000}$ of an inch. They are uniformly spheroidal, retaining their rounded contour even after the addition of dilute acetic acid. They are so firmly kept together by the connective substance that it is difficult to examine them apart. So far as can be ascertained most of them seem to be surrounded by a cell wall, others by irregular masses of transparent material, which may be probably regarded rather as bits of interstitial substance than as vesicular membranes, while others again seem to be the centres of stellate or caudate fibre corpuscles. (Plate I. fig. 1.) The relation between the adenoid tissue and the ducts and vessels resembles that which is seen in the lung. In every section of an interlobular grey mass one or more bile ducts can be seen lined with characteristic epithelium, and closely surrounded by masses of adenoid tissue. As was observed with reference to the bronchial tubes, so in the liver, the epithelium of the bile duct is entirely unchanged. The relation of the new tissue to the hepatic arteries is similar. The arteries are embedded in it, but are not themselves altered, nor do I see any ground for the belief that the disease commences in their sheaths.

Relation of the two lesions to each other.

The relation between the interstitial new growth and the islands is not so clear as could be wished. The absolute whiteness of the islands in their early state seems to indicate that they are entirely cut off from the circulation. It cannot be supposed that this is due merely to the obstruction of the hepatic arteries by the development of adenoid tissue around them, for in several instances I have met with livers in which no islands existed, notwithstanding that the new growth evidently constituted the greater part of the bulk of the organ. The only explanation that suggests itself to me is that in those acini which are surrounded by new growth, the intralobular circulation is so compressed as to render them anæmic; for it is not difficult to understand that in a portion of liver which is the seat of adenoid degeneration such lobules as remain in a comparatively unaltered condition will be likely to become anæmic. However this may be, it is evident that an island once formed is as much out of the circulation as an embolic infarct in the spleen or kidney, which it resembles in being bordered by a ring of venous congestion.

5. *Appearances observed in the Spleen.*

General nature of the lesions observed.

The morbid appearances observed in the spleen as examined with the naked eye are of the following nature. The organ may be enlarged without appreciable change of structure, or may at the same time exhibit on section disseminated miliary grains which appear to be malpighian corpuscles. More frequently there is evidence of new growth in the form of rounded projections of its external surface, the pale whitish grey colour of which contrasts strongly with the natural redness of the organ. These nodular prominences vary both in size and arrangement.

Increase of weight.

In its natural state the spleen of a guinea-pig is about half an inch long, and weighs from half a gramme to a gramme, that is, about one-thousandth of the weight of the body. In inoculated animals its size and weight are enormously increased. Thus in ten cases of well-marked disease the average weight was found to be 1·1 per cent., that is more than ten times its weight in health. The heaviest spleen observed weighed 9½ grammes, that is 27 times its natural weight. Another weighed 8 grammes, and measured more than two inches in length. The organ was enlarged with or without structural alteration in 20 out of the 21 animals. In the exceptional case its weight was normal. As,

however, the animal died in my absence, and was not examined by myself, I cannot state positively that it was not diseased.

In nine of the 21 infected animals there was simple enlargement without appreciable change of structure. In two of these no granulations could be distinguished, the sectional surfaces appearing homogeneous. In the rest they were obvious, but their size scarcely equalled that of a millet seed. By microscopical examination I was unable to detect any structural peculiarity. Of five of these enlarged but otherwise healthy spleens the respective weights were 3·1 grammes, 5·6, 6·3, 8·3, and 9·5 grammes. The other two were not weighed, but one of them measured nearly two inches and a half in length.

Aggregate miliary nodule

In nine animals the external surface of the spleen was beset with miliary nodules, which projected considerably, and on making sections it was found that similar rounded masses were scattered throughout the organ. These nodules possess a very firm consistence, and have the characteristic semi-translucent appearance of grey tubercle, so that a section of the organ has a striking resemblance to a section of hyperæmic and airless human lung beset with miliary granulations. On cutting into them it is found that the smaller nodules are transparent throughout, but that each of the larger ones exhibits a central opacity. They are surrounded by the natural tissue, which exhibits no appearance of hyperæmia, and can be readily enucleated from it without carrying with them any adhering spleen pulp.

Conglomerate nodules in masses.

In two of the animals the nodules were of the same general character, but instead of being disseminated throughout the surface and substance of the organ they were aggregated in groups in different parts. Each of these groups gave rise to a circular projection which assumed a form similar to the so-called tubercles which are met with in cancerous disease of the human liver. In all of them the margin was more prominent than the centre. On making sections of these tuberosities, each was shown to be due to a mass of the same semi-transparent material as that which formed the smaller nodules. Most of them projected on the external or convex side of the organ. As, however, their diameters were equal to its thickness, they could also be felt and seen on its concave aspect although they were not so prominent. The sectional surfaces were irregularly mottled with transparent white, opaque yellowish white, and red; the first being most abundant towards the circumference of the nodosity, the second in the central parts—a fact which seemed to indicate that each tuber is produced, not by the extension of a single nodule, but by the growth of a number of nodules round a previously existing central mass. The sections further showed that in these animals the white material was not separated from the healthy structure by so circumscribed a line as in those cases in which the deposit assumed a nodular form. For this reason the masses could not be readily enucleated.

Sanguineous infiltration.

In one of the animals (No. 14) the condition of the spleen was exceptional. It exhibited two or three nodules of the usual grey colour and firm consistence; but in addition several black red patches, of irregular contour, and very slightly depressed below the general surface of the organ, presented themselves. On making sections it was found that the splenic pulp was in these parts infiltrated with coagulated blood. The organ was placed in chromic acid for examination, but was accidentally spoilt. It weighed three grammes. The morbid appearances in the lungs and liver of the same animal were well marked.

Minute anatomy of the nodular growths.

Microscopical Dissection.—In my examination of the nodules in the recent semi-transparent condition which is most frequently observed, I have been unable to detect any characters by which their

elements can be distinguished from those of the malpighian corpuscles. I have, however, obtained no evidence that they actually originate from previously existing malpighian bodies, or that they have any connexion with arterial branches.* The structure which they exhibit is strictly analogous to that of the adenoid growths already described, and particularly to those which are found in the liver. Fine sections show that each nodule consists of cellular elements embedded in the holes of a vesicular matrix. The paleness of the whole mass is owing to the absence of those venous dilatations to which the spleen owes its peculiar colour, and especially of the blood pigment granules which the sinuses contain in considerable number. In nodules which are opaque in their centres the microscopical appearances resemble those observed in the central softenings of the pulmonary nodules. The change which the opacity indicates is due to the breaking up of the nuclei, and the existence around and among them of innumerable fat granules. In several instances I have found, in making sections of nodules with opaque centres, that the degeneration was not only fatty but calcareous. Under the microscope the calcareous deposit had the form of angular or botryoidal grains. (Plate I., fig. 10.) On the addition of dilute hydrochloric acid to these masses they disappeared with effervescence, leaving a granular fatty detritus behind them.

In the formation of nodules in the spleen, as in the lymphatic glands, we have an example of a process which seems to stand midway between hypertrophy and new growth. The original structure of the nodule cannot be distinguished from that of the tissue in which it originates, *but its development is different.* Normal in its anatomy, it proves itself to be morbid by undergoing fatty degeneration and necrosis.

6. *Appearances observed in the Kidneys.*

Of the 21 animals one only exhibited morbid changes in the kidney. In this case the lesion consisted in the existence of two or three nodules as large as hemp seeds in the cortical substance. These were of firm consistence, and in their microscopical characters resembled those found in the spleen. They were not examined with the microscope.

7. *Appearances observed in the Internal Lymphatic Glands.*

In all cases in which there was disease of the thoracic or abdominal viscera, the internal lymphatic glands were found to be affected. The alteration consisted in enlargement and induration, with caseous degeneration. Neither suppuration nor softening were observed in a single instance. The degree in which the several groups of glands were enlarged appeared to be invariably dependent on the extent and progress of the morbid changes which had taken place in the organs from which they received their tributaries. In those cases in which the lung, for example, remained healthy, although other organs were diseased, the bronchial glands were also found in a natural condition; but in cases like Nos. 21 and 22, in which by far the greater part of the parenchyma of the lung was the seat of interstitial induration, the bronchial glands formed a mass in the upper part of the thorax, consisting partly of the indurated and enlarged organs themselves, partly of

* If it were true, as is now held by many pathologists, that all tuberculous granulations originate in the sheaths of the minute arteries, the resemblance between a splenic malpighian corpuscle and such a granulation would be complete, each of them consisting of a dilatation of the tunica adventitia, filled with lymph corpuscles.

condensed cellular tissue, by which the vessels and other organs contained in the posterior mediastinum were matted together. In a similar manner the size and hardness of glands in the gastro-hepatic omentum afforded a sure indication of the state of the liver, with which in the more advanced cases they were connected by a cord of induration. The agminated glands of the small intestine, and particularly the large patch which is always found close to the ileo-cæcal valve, appeared to me to be usually healthy. Sometimes the follicles were enlarged, in which case enlargement was also found of the corresponding mesenteric glands.

8. *Appearances observed in the Peritonæum.*

These appearances can be best studied in the mesentery and in the gastro-hepatic omentum. They were met with only in a small proportion of the animals examined. On spreading the diseased membrane on a plate of glass it can be made out even with the naked eye that its surface is scattered with minute granulations; and on examining the specimen under a low power it at once becomes manifest that these granulations have a special relation to the vascular branches, and are only to be found in their immediate neighbourhood. The nodules are round or oval, and vary indefinitely in size. I have seen none which exceeded a large pin head in diameter, while others are so small that they can only be discovered by the microscope. Here and there they are so numerous that the vessels resemble, as seen by transmitted light, necklaces of dark beads, some of which look as if they were strung on the artery, others as if they were attached to one side of it.

Their structure and true relation to the arteries is as follows:—They consist of corpuscles which have the same character as those which constitute the new growths in the liver and in other organs. Near the external surface of each granulation, some of the corpuscles are spindle-shaped, so that they are undistinguishable from the nuclei of the peritonæal connective tissue. But those which form the mass of the growth are oval or spheroidal. They are held together by a structureless stroma, which, however, is much less obvious than in the liver and other parenchymatous organs.

Although, as above stated, the granulations are always to be found in the closest relation with vascular branches, it does not appear that they can be regarded as outgrowths of the arterial adventitia. From the examination of those growths, which are to be found on arteries scarcely larger than capillaries, one might easily be led to an opposite conclusion, for these vessels present an appearance which cannot be distinguished from that so frequently seen in the pia mater when that membrane is the seat of tuberculous disease. But in granulations attached to arteries from a twentieth to a thirtieth of a line in diameter, it appears to me evident not only that the newly formed corpuscles are not identified with those of the tunica adventitia, but that they lie altogether outside of it, so that that structure can be traced between the granulation and the muscular coat of the vessel. The relation between the granulations and the vessels can be easily understood if it is borne in mind that all the larger mesenteric and epiploic arteries, along with their accompanying veins and nerves, are inclosed in cylindrical sheaths of areolar tissue loaded with fat cells. It is in these sheaths that the granulations are situated, hence it follows that they lie among the fat cells, and are in contact with them. Around the smaller vessels the areolar sheath cannot be distinguished from the adventitia, and hence the nuclear proliferations with which they are encrusted look as if they formed part of the vascular wall.

No. 6. *On the Communicability of Tubercle by Inoculation, by Dr. Sanderson.*

Observation relating to the Inoculation of diseased Tissue from the supra-renal Capsule of a Patient affected with Addison's Disease.

As the morbid process which occurs in the affected organs in this disease is regarded by some pathologists as distinct from the tuberculous, this experiment is separated from the preceding, although the results were identical.

Observation X. Inoculation of diseased tissue of supra-renal capsules.

Obs. X., May 29th.—Two guinea-pigs were inoculated with grey, semi-transparent material, from the supra-renal capsule of a female patient, aged 19, who died, under the care of Dr. Murchison, in Middlesex Hospital, affected with Addison's disease. The following were the most important lesions. The hair exhibited the usual variations of colour, the skin was anæmic but not discoloured, but there were dark patches on the inside of the left cheek. There was an old fibrous adhesion between the apex of the right lung and the pleura, and a similar adhesion of its diaphragmatic surface. The apices of both lungs were puckered and cicatrized, and contained small indurations, with calcareous degeneration. On the left side there was a small cavity surrounded by induration. In other respects the lungs and pleuræ were normal. The bronchial glands were enlarged and pigmented. The solitary and agminated glands of the lower part of the ileum were enlarged and opaque. Similar appearances were observed in the stomach and duodenum. The mesenteric glands were also enlarged and indurated. The supra-renal capsules were much enlarged and indurated, and exhibited a nodulated form. On section they were found to consist of semi-transparent grey material, the sectional surfaces of which showed irregular patches of yellow opacity.

No. 23. Died 36 days after inoculation. *Inoculation wound:* A flattened tumour as large as a fourpenny-piece, showing on section indurated cellular tissue, scattered with minute opaque grains of yellowish white material (caseous abscesses). *Lungs:* Weight 3·3 grammes. Numerous disseminated nodules, grey and gelatinous in their centres, pigmented marginally, all of them minute. Most are sub-pleural, but many are scattered throughout the substance of the organ. *Liver:* Weight 15·4 grammes; relation of actual to normal weight 3 : 1.* General interlobular mottling of the whole organ, the acini being separated from each other by a grey reticulum, which in some parts is so abundant that the intervals are reduced to mere dots of redness, while in others they entirely disappear. The sectional surfaces exhibit a similar mottled aspect, the grey appearing more transparent than it does externally. One or two islands only are observed. *Spleen:* Weight 1·5 grammes; relation of actual to normal weight 12 : 1. Tissue apparently natural. State of lymphatic glands not noted.

No. 24. Died 39 days after inoculation. *Lungs* perfectly healthy. *Liver:* Numerous minute islands, both superficial and in the substance of the organ. *Spleen:* Weight 2·2 grammes; relation of actual to normal weight 15 : 1. The tissue was apparently natural. On its external surface, and scattered throughout the tissue, were numerous prominent semi-translucent miliary nodules. These nodules were used for inoculating other animals.

From this experiment it is evident that no distinction can be drawn between the effects of inserting the material which constitutes the induration of the supra-renal capsules in Addison's disease, and of the

* It is assumed, as stated above, that the relative weights of the organs in the guinea-pig, the weight of the whole body being 100, are—lungs, 1; liver, 4; spleen, 0·1.

inoculation of tubercle. This conclusion was confirmed by the results of re-inoculation. The value of the experiment, however, is somewhat diminished by the fact that in the lungs of the patient from whose body the material was obtained there were indications of obsolete tubercle.

SECOND SERIES.—EXPERIMENTS RELATING TO THE INOCULATION OF MATERIAL FROM THE DISEASED ORGANS, OR OF BLOOD OF ANIMALS PREVIOUSLY INOCULATED.

Secondary inoculations.

Observation XI. Inoculation of diseased tissue from spleen.

OBS. XI., June 11th.—Three guinea-pigs were inoculated with material of nodules in spleen of No. 1.

No. 25. Killed 119 days after inoculation. *Wound* contains pus, and is surrounded with induration. Numerous masses of caseous material embedded in indurated connective tissue (old abscesses), but no abscesses containing fluid pus, were found in the subcutaneous tissue in the neighbourhood, over a space extending from the dorsal spines towards the axilla. Enlargement, induration, and opacity of the subcutaneous glands, particularly the scapular and tracheal glands of the same side as the wound. *Lungs:* Very numerous equally disseminated nodules, many not larger than pin heads. They are grey centrally, pigmented marginally, many having shreds of lymph attached to their sub-pleural surfaces. Intervening parenchyma pale. *Liver:* Weight 31 grammes; relation of actual to normal weight 1·5 : 1. No islands. Interstitial deposit of grey semi-transparent material abundant, but very unequally distributed. In the left lobe it assumes the form of nodular growths as large as hemp seeds; some of them are softened centrally and contain opaque material of creamy consistence. *Spleen:* Weight 3·7 grammes, relation of actual to normal weight 7 : 1. Concave surface smooth. On the convex aspect of the organ, conglomerate nodular masses of three to four lines in diameter exhibiting previously described characters.

No. 26. Killed 87 days after inoculation. *Wound* contains no pus. Two small abscesses in its neighbourhood, the contents of which are caseous. Scapular gland of the same side enlarged, indurated, with partial caseous degeneration, the rest of the gland being of semi-transparent appearance. Other subcutaneous glands not affected. *Lungs:* Numerous and equally disseminated nodules, the largest little more than half a line in diameter. They differ from those previously observed in the complete absence of pigment. *Liver:* Weight 21 grammes; relation of actual to normal weight 2 : 1. A few small islands along sharp margin of left lobe, otherwise healthy. *Spleen:* Weight 6 grammes; relation of actual to normal weight 22 : 1. One or two minute nodules along outer margin. Tissue apparently healthy, but unusually firm. Malpighian corpuscles not distinguishable. Bronchial and hepatic glands enlarged and indurated.

No. 27. Died 77 days after inoculation. *Wound* contains a quantity of pus. There are no abscesses in its neighbourhood. Scapular gland of the same side enlarged and indurated, not softened. *Lungs:* Disseminated nodules of unusual hardness occur in different parts; one in the lower lobe of the left lung, as large as a hemp seed, contains a central cavity, and another in the same lung is grey and solid. There are five similar nodules in the right lung. *Liver:* Weight 21 grammes; relation of actual to normal weight 1·3 : 1. Several islands in each lobe, the largest two lines in diameter. Many of them exhibit softening and bile staining in their centres. Each island is surrounded by apparently healthy liver tissue. In addition to the nodules the bevelled edge of one of the lobes of the liver is completely converted into the same material as that which forms the islands. *Spleen:* Weight 3·5 grammes; relation of actual to normal weight 11 : 1. Innumerable miliary nodules, the largest a line in diameter, on convex surface, which are so close to

each other that scarcely any of the natural structure of the organ can be seen. They are scattered in corresponding abundance throughout its substance.

In this observation, in which the period intervening between inoculation and dissection was longer than before, the retrogressive changes by which the disease would probably have undergone spontaneous cure under favourable circumstances were seen in each case.

Observation XII. Inoculation of diseased tissue of spleen.

Obs. XII., June 25th.—Three guinea-pigs were inoculated with material of nodules in spleen of No. 2.

No. 28. Died 16 days after inoculation. A sub-peritoneal abscess existed between two lobes of the *liver*, and there were two other abscesses in the gastro-hepatic omentum. The other organs were healthy. The liver and spleen were of the normal weight.

No. 29. Died 22 days after inoculation. *Wound* contains pus. The subcutaneous cellular tissue and panniculus from the vertebral spines to the middle line—that is over the whole left flank—are scattered with minute circumscribed abscesses. The glands in both axillæ are enlarged and softened, some of them being converted into abscesses containing a quantity of creamy pus. The left inguinal glands are also enlarged and softened. *Lungs:* Disseminated nodules, all with one exception, smaller than pin heads. In the left lung 24 were counted, six in the lower and 18 in the upper lobe; in the right lung 40, 18 in the lower lobe, 10 in the middle lobes, and 12 in the upper. The larger nodules project considerably, having grey centres and almost black margins. *Liver* of natural weight. Innumerable islands, all of which are edged with a deep margin of injection, scattered over the surface and throughout the substance of the organ. Tissue otherwise natural. *Spleen:* Weight 0·7 gramme; relation of actual to normal weight 1·4 : 1. The organ is beset with minute miliary nodules.

No. 30. Killed 148 days after inoculation. *Wound* cannot be discovered. There is no induration of the subcutaneous cellular tissue, and there are no abscesses. The scapular gland of the left side is much enlarged and indurated, but not softened. The other axillary glands are also enlarged; other lymphatic glands normal. *Lungs:* A few disseminated nodules, none larger than one-fifth of a line in diameter. *Liver* perfectly healthy. *Spleen* contains numerous semi-transparent nodules. The animal was inadvertently not weighed.

Observation XIII. Inoculation of blood of diseased animal.

Obs. XIII., June 25th.—Three guinea-pigs were inoculated with blood taken from the heart of No. 2 immediately after it was killed. The mode of inoculation was the same as in the other experiments, not more than a drop of blood being employed.

No. 31. Died 80 days after inoculation. *Wound* could not be discovered; there was no subcutaneous induration. The tracheal and submaxillary glands on both sides of the neck are enlarged and indurated externally, softened and pulpy in their centres. The axillary and inguinal glands are healthy. *Lungs:* Four or five disseminated nodules, smaller than pin heads in the right lower lobe; two or three in the right upper. Two nodules of larger size in the left lung. *Liver* not weighed; apparently not enlarged. Five or six characteristic islands, varying in diameter from half a line to a line and a half, softened and bile-stained in their centres, and edged with injection, are observed. *Spleen:* Four or five conglomerate nodular masses project on the convex surface of the organ.

No. 32. Killed 105 days after inoculation. *Wound* contains pus, and is surrounded by induration. Numerous disseminated abscesses in subcutaneous cellular tissue. Right scapular gland much enlarged and softened. Tracheal glands slightly enlarged. Inguinal glands enlarged

and softened. *Lungs:* Numerous disseminated nodules as large as pin heads. *Liver:* Weight 33 grammes; relation of actual to normal weight 1·3 : 1. A grey interstial nodule in the middle lobe, similar to that observed in No. 25. *Spleen:* Weight 3 grammes; relation of actual to normal weight 5 : 1. It contains conglomerate nodular masses.

No. 33. Died 130 days after inoculation. *Wound* is open, but contains no collection of pus. The surrounding subcutaneous thickening is less than usual. There is a subcutaneous abscess over the gluteal muscles on the right side. Its wall is extremely thin, and it contains cheesy pus. Scapular glands large and indurated, but less enlarged than usual. Tracheal glands in the same condition. *Lungs:* Disseminated nodules somewhat larger than usual, exhibiting much central opacity. *Liver:* Weight 45 grammes; relation of actual to normal weight 2·7 : 1. No islands. Interlobular mottling of the whole surface with characteristic alteration of form. On microscopical examination the interlobular adenoid growth was found to be abundant in every part of the organ. *Spleen:* weight 10·2 grammes; relation of actual to normal weight 25 : 1. It is smooth and of natural form. In section some parts appear pale, others intensely hyperæmic, but there are no nodules. The bronchial and hepatic glands and those of the splenic omentum are enlarged and indurated.

Observation XIV. Inoculation of diseased tissue from spleen.

OBS. XIV., July 7th.—Two guinea-pigs were inoculated with material from the spleen of No. 24.

No. 34 (Notes by Mr. David Guillod). Died 35 days after inoculation. *Wound* contains cheesy material, surrounded by induration; no abscesses. Axillary glands much enlarged, with cheesy degeneration, but no suppuration. *Lungs* healthy. *Liver:* Weight 14·5 grammes; relation of actual to normal weight 7 : 1. Ten or twelve characteristic islands two lines in diameter; tissue of organ apparently healthy. *Spleen:* Weight normal. Two nodules as large as pin heads.

No. 35. The body was not discovered till August 31st, that is two or three days after death, and 55 days after inoculation. It was putrid. The *spleen* contained characteristic deposits, but the other organs appeared healthy.

Observation XV. Inoculation of apparently healthy tissue of supra-renal capsule of a diseased animal.

OBS. XV., July 7th.—Two guinea-pigs were inoculated with material from the apparently healthy supra-renal capsules of the same animal, No. 24.

No. 36. Died 114 days after inoculation. *Wound:* Breach of continuity at point of inoculation covered with a scab, about half an inch from which is a mass of thick, tough, cellular tissue adherent to the integument, riddled with interstices containing caseous pus. Scapular, tracheal, sub-maxillary, and inguinal glands of left side enlarged and softened. No enlargement of glands on right side. *Lungs:* Five or six nodules in left lung, one of which near the apex is as large as a hemp seed. It is hard externally, softened centrally, and scarcely projects above the surface. The other nodules are much smaller. Numerous similar nodules in the right lower lobe. The right upper lobe adheres loosely to the pericardium and wall of the chest by a layer of granular lymph, which is in some parts continuous, in others consists of subpleural granulations scarcely distinguishable without a lens. *Liver* of natural size, one or two small islands in the right lobe. *Spleen* much misshapen, and about 20 times its natural size. Seven conglomerate nodular masses can be distinguished; the largest of these, occupying the centre of the organ, is as wide as a threepenny-piece; its depressed and softened centre is white, the convex margin being of a reddish white.

Its sectional surface is white superficially, white, mottled with red, more deeply. Yellow opacities occur, which grate against the knife. In the smaller nodules there is no grittiness. Bronchial glands enlarged and indurated; their sectional surfaces exhibit yellow and opaque patches. The condensed cellular tissue around the æsophagus is beset with white miliary nodules. Hepatic glands also enlarged.

No. 37. Killed 136 days after inoculation. *Wound:* Over the upper dorsal spines was a mass of indurated cellular tissue, containing much fat in its areolæ; on puncturing this mass pus escaped. Both scapular glands enlarged, particularly the right. The other axillary and the tracheal glands were also enlarged and indurated. Their sectional surfaces were for the most part transparent, but showed opaque patches, which grated against the knife. *Lungs:* Numerous disseminated sub-pleural nodules, all of which were semi-transparent. *Liver:* No islands; semi-transparent interstitial deposit exists throughout the organ, most abundantly in the left lobe, where it assumes a nodular form. *Spleen* contains several conglomerate nodular masses, the largest of which is three lines in diameter. Hepatic and bronchial glands enlarged and indurated.

Tertiary inoculations.

THIRD SERIES.—EXPERIMENTS RELATING TO THE INOCULATION OF MATERIAL FROM THE DISEASED ORGANS OF AN INOCULATED ANIMAL OF THE SECOND SERIES.

Observation XVI. Inoculation of diseased tissue of spleen.

OBS. XVI., October 8th.—Four guinea-pigs were inoculated with material from the spleen of No. 25.

No. 38. Killed 56 days after inoculation. *Wound:* No suppuration, and very slight induration. Scapular gland much less enlarged than in animals previously examined; other axillary glands also slightly enlarged. Neither were softened. *Lungs* and *Liver* healthy and of natural weight. *Spleen* not enlarged; contains two miliary nodules, and its malpighian corpuscles are distinct, and apparently enlarged. The animal was a large boar, and in good condition.

No. 39. Killed 56 days after inoculation. Scapular gland of left side somewhat enlarged, and slightly softened. Other subcutaneous glands healthy. *Lungs:* Characteristic disseminated nodules, varying in size from one-fifth of a line to a line in diameter, the larger ones having opaque centres, the former being transparent throughout. All exhibit the usual marginal pigmentation. They were carefully examined, and found to present the structural characters described at p. 7. *Liver:* Weight 19·5 grammes; relation of actual to normal weight 1·5 : 1. No islands. The external surface exhibits patches of grey mottling, which are particularly abundant near the sharp margins of the right lobe. *Spleen:* Weight 2 grammes; relation of actual to normal weight 6 : 1. Convex surface beset with miliary nodules of remarkable transparency. Bronchial and hepatic glands, particularly the former, enlarged and indurated.

No. 40. Killed 81 days after inoculation. *Wound* unhealed and surrounded by slight subcutaneous condensation and thickening. A small abscess, two lines in diameter, between panniculus and skin, not connected by a cord with the wound, from which it is half an inch distant. Another similar abscess at the same distance, leading to which a cord can be distinguished. Of these two abscesses the former contains caseous, the latter fluid pus. Left scapular gland enlarged and suppurated; right scapular and one or two tracheal glands enlarged and caseous. Other subcutaneous glands healthy. *Lungs* healthy. *Liver:* apparently healthy. Traces of interstitial deposit. *Spleen:* Conglomerate nodular deposits, none exceeding three lines in diameter.

The nodules of which they are composed are opaque internally, semi-transparent externally.

No. 41 is still under observation.

In the preceding experiments of the second and third series the morbid appearances differed in no important respect from those observed in animals inoculated directly with tuberculous material. It is, however, worthy of notice that, although in some of the animals the subcutaneous lesions were quite as extensive as in the experiments of the first series, the local effects were on the whole slighter, and in several instances very inconsiderable. It is also worthy of remark, as regards the morbid appearances in the liver, that in two or three animals, particularly in Nos. 25, 32, and 37, the interlobular new growth was so exuberant in some parts of the diseased organs that it formed distinct nodular masses,—a circumstance not before observed. In other animals the grey mottling was entirely absent. I am, however, inclined to anticipate that in the further progress of the inquiry it will be found that, whenever the liver is enlarged, interstitial adenoid growth really exists and could be detected by the microscope, even though to the naked eye there seem to be no indications of structural change.

In concluding this section of my inquiry I draw attention to the following facts, as established with some degree of certainty, and as having an important bearing on the question of the development of the morbid process, that is on the mutual relation of the several lesions to one another :—

1. Suppuration occurs in nearly all cases under the skin at the point at which the tuberculous material is inserted; and in most, the suppurative process is propagated to the subcutaneous areolar tissue in its neighbourhood. It is, however, not essential to the production of the internal lesions; for in two cases there was no trace of suppuration anywhere around the wound.

2. In every infected animal the lymphatic glands corresponding to the place of inoculation were enlarged; usually there was softening; there was always caseous degeneration.

3. In eight infected animals the lungs were free from disease.

4. The liver was probably in no instance absolutely healthy, but the lesions were very variable, no less in their nature than in their extent.

5. In one animal the spleen appeared to be of natural size and structure. With this exception, the organ was always enlarged. In many animals there was no apparent change of structure. In others there were new growths, which appeared to consist of overproduction of those elements which the spleen has in common with lymphatic glands.

5. The internal lymphatic glands receiving their tributaries from diseased organs were always themselves enlarged, indurated, and caseous.

The results of the three series of experiments now related afford an answer to the first of the questions proposed at the outset, so far as relates to the species of animal used. They show that the inoculation of tuberculous matter produces in guinea-pigs morbid changes so constant both in their anatomical character and development that they may be regarded as constituting a disease; for in all the organs the appearances observed are much less variable than those we are accustomed to find in idiopathic tuberculous disease of man. The true relation of the human disease to its bestial derivative cannot yet be determined.

The second part of the question cannot be decisively answered at the present stage of the inquiry. Anatomically the disease may be defined as primarily an overgrowth of the lymphatic glands, and of

those structural elements of other organs which they have in common with the lymphatic glands. But anatomical characters afford no sufficient basis for a definition.*

Part II.—Previous Researches.

Ever since Laënnec † produced a growth which he regarded as tuberculous, on the forefinger of his left hand, by accidentally scratching it with a fragment of bone while engaged in the post-mortem examination of a patient who had suffered from vertebral caries, the notion that tubercle might be communicated by inoculation has from time to time suggested itself to the minds of various pathologists. It was not, however, until Villemin drew attention to the many facts which render it probable that tuberculosis is the manifestation of a morbid action pervading the whole organism, and that in its development and propagation it is governed by the same conditions as the so-called zymotic diseases, that the subject assumed its present importance. It was the consideration of these facts, and particularly of the close relation which seemed to him to exist between tubercle and a disease peculiar to the horse, viz., farcy, that induced M. Villemin to undertake those remarkable experiments which form the basis of the present inquiry. From these experiments he concluded that tuberculosis must no longer be regarded as a constitutional malady, but as one dependent on a specific infection,—in short, as a zymotic disease.

Since the publication of these results other pathologists in France, England, and Germany have followed in Villemin's track. The fact that a morbid process, having a certain general resemblance to that by which tubercle is formed, is set up in animals inoculated with tuberculous material, has been abundantly proved, but the interpretation given by different observers differs widely. In order as much as possible to separate facts from inferences, and at the same time to furnish the reader with a complete and intelligible view of the present state of the question, I propose to divide the following summary of previous researches into three sections. In the first, the nature of the experiments will be briefly recorded; in the second, an account will be given of the anatomical characters of the lesions observed in inoculated animals; and in the third, of the theories which have been advanced in explanation of them.

Section I.—Experiments.

M. Villemin's first series of experiments.

On the 5th of December 1865 M. Villemin communicated to the Academy of Medicine of Paris a paper in which the results of the inoculation of ten rabbits were given. In these experiments the material used was always mixed, some of it being grey, the rest caseous. The mode of inoculation consisted in passing the blade of a narrow bistoury under the skin, near the base of the ear, and introducing the material into the wound, after breaking it down with the point of the knife.

The first inoculation of mixed pulmonary (caseous) and intestinal (grey) tubercle was performed on the 6th of March 1865, and repeated in the same animal on the 30th of March and the 4th of April. It was killed on the 20th of June, when "tubercular masses" were found in

* If the chemical nature of that transformation of tissue which gives cheesy yellow tubercle as its result, were more thoroughly understood, it would probably be possible to found a definition upon it.

† Traité d'Auscultation Médiate, 1837, Forbes's Translation, p. 331.

the lungs, and granulations under the peritonæum. On the 15th of July three rabbits were inoculated, the operation being repeated on the 22nd, when a fourth rabbit was inoculated for the first time. About two months afterwards they were killed. "Pulmonary tubercles" were found in each case, and there were also "tubercles" beneath the peritonæum. Three rabbits were inoculated on the 2nd, and again on the 24th of October, on which day a fourth rabbit was inoculated for the first time. In all these animals, which were examined about a month after the second inoculation, granulations, regarded by M. Villemin as tuberculous, were found in the lungs.*

M. Villemin's second series of experiments.

In a second paper, communicated to the Academy on the 30th of October 1866, M. Villemin relates the results of subsequent experiments on 12 other rabbits inoculated with "tuberculous granulations." Four of these experiments failed, three of the animals dying of diffused subcutaneous purulent infiltration only a few days after the operation. In the other, which was killed six months after inoculation, no lesions were found. The animals successfully inoculated were killed from two to six months after inoculation. Tubercle was found in the lungs and other organs, it being observed that in those that lived longest the tuberculous deposits were more or less yellow and softened, whereas in those in which the interval was shorter the deposits were grey.† In the unsuccessful case, M. Villemin attributes the failure to the insufficient evolution of the tubercle employed.

In addition to his experiments on rabbits, M. Villemin has also employed other animals. On the 19th of December 1865 two guinea-pigs were inoculated, one of which was found dead on the 21st of February, the other on the 31st of March. Both exhibited numerous tubercles in the lungs, liver, spleen, and lymphatic glands. About the same period several dogs were inoculated with material of grey granulations. In three that were killed several months afterwards, no traces of tubercle could be discovered. But in the other, which was three times inoculated, and killed five months after the first inoculation, subpleural granulations were found which were regarded as tuberculous. The lungs, however, were perfectly healthy. The result of this experiment was regarded by M. Villemin as doubtful, but on a subsequent occasion (June 24th 1866) he was more successful. The animal was killed three months after inoculation, when characteristic granulations were found in the lungs, liver, kidneys, spleen, and mesentery. In three inoculations of cats no satisfactory results were obtained. The experiments on goats, sheep, and fowls were also unsuccessful.

M. Villemin's secondary inoculations.

On the 30th of April two young rabbits were inoculated with material from the lungs of another inoculated rabbit just killed. One was killed six weeks after the operation, and the other was found dead two weeks later. In the former there were numerous tuberculous granulations in the lungs and spleen. In the latter both lungs were so completely filled with tubercle that scarcely any sound tissue remained. The liver and spleen were also tuberculous. The details of five similar experiments made at subsequent periods will be found in M. Villemin's "Études sur la Tuberculose," pp. 542–545.

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* At the same time with these experiments other animals were inoculated with other morbid products, particularly with pus from phlegmonous abscesses, and from a carbuncle. These experiments were without result.

† The details of these experiments are given at length in the Bulletins of the Academy of the dates corresponding, as well as in M. Villemin's Work, "Etudes sur la Tuberculose," Paris, 1868.

Mr. Simon's experiments.

On the 19th of March 1867, Mr. Simon communicated to the Pathological Society of London, the results of some experiments made by him for the purpose of verifying M. Villemin's statements.

In June 1866, he inoculated 10 rabbits with softening yellow tubercle, taken from the lungs of a patient who had died of phthisis 20 hours before. The following November, nine of them were killed. On dissection, it was found that in five the lungs presented appearances resembling those of tuberculous disease, but that in the others they were healthy. From the masses contained in these lungs, three other rabbits were at once inoculated, of which two were killed in March, 1867. In both there were extensive tuberculous consolidation of the lungs and enlargement of the mesenteric glands, while in one lesions of a similar character were found in the spleen and liver. In commenting on these results, Mr. Simon confined himself to pointing out that the aspect and common physical properties of the product were entirely those which in man we call tubercular, and that although it for the most part resembled yellow tubercle, the small rounded masses seen in the lungs were found, when slightly magnified, to have a semi-transparent grey circumference. The diseased organs were submitted to a committee of the Pathological Society for further examination, who subsequently reported that the masses found in the lungs and other organs resembled crude tubercle in their macroscopical characters, in their minute structure, in the tendency observed in them to induration and earthy degeneration, and finally in their being found in those organs which are the ordinary seats of tubercle.*

Prof. Lebert's experiments.

The experiments of Professor Lebert, which relate not merely to the transmissibility of tubercle, but to that of various other inflammatory products and new growths, from man to animals, are divided by him into five groups, comprising 45 experiments. The first group relates to the inoculation of what Lebert regards as typical tubercle. Eleven animals were employed of which five were guinea-pigs and six rabbits. The material used was taken from the bodies of patients affected with phthisis, in whom the lesions were of the following character. In only one case was there acute pulmonary tuberculosis, in three instances there were vomicæ and pneumothorax, associated with pneumonic infiltration and disseminated secondary granulations, some of which were grey and others yellow, both being employed in inoculations. In two cases the pulmonary lesion consisted exclusively in yellow disseminated pneumonic masses with vomicæ; in two others there were chronic pneumonic masses and peribronchitic foci without cavities, while in another there was diffused chronic pneumonia. In the remaining two experiments the material used was taken from the mesenteric glands of a child who had died with pneumonic masses in the lungs and tubercular granulations elsewhere. All of these experiments were successful, nor could any difference in the result be observed, notwithstanding the great variety of the materials employed.

Inoculation of typical tubercle. Expts. 1–11.

Inoculation of pus. Expts. 12–13.

In the second group, consisting of two experiments, (dogs) pus was injected, not into the cellular tissue but into the jugular vein. In one case the injection was performed four times within three weeks, six grammes being used each time, the last inoculation being followed by diarrhœa and vomiting, and lastly by emaciation, &c. When the animal was killed 34 days after the first injection numerous disseminated abscesses were found in the lungs, and nodules varying in size from that of a pin head to that of a lentil in the liver. The other experiment was

* Trans. of the Pathological Society, vol. xviii., p. 290.

similar, but the results were different. There were "grey semi-
" transparent granulations . . . situated partly in the alveoli, partly
" between the pulmonary fibres; the apices of both lungs were
" adherent . . . The liver contained numerous greyish yellow nodules
" of the same constitution and character as those in the lungs."

In the nine experiments of the next group bronchial and cavernous secretion was used, six of the patients being affected with chronic pneumonia, the rest with pulmonary gangrene. No granulations were found in the internal organs, the animals dying rapidly, apparently of septicæmia.

Inoculation of bronchial and cavernous secretion. Expts. 14–22.

Next follows a single observation relating to a dog which died three days after the injection of phosphorous oil per rectum, having a fortnight before undergone the operation for biliary fistula (Bernard's operation). In this case "numerous nodules as large as pin heads were found on the
" pulmonary pleura, each of which exhibited a central dark blackish
" point . . They did not extend to the parenchyma. Numerous small
" nodules scarcely as large as pin heads of a pale grey colour and firm
" consistence . . . resembling the granulations produced by inoculation
" in the animals of the first group, were found in both lungs." On microscopic examination it was found that the nodules possessed the same structure as those existing in animals inoculated with tubercle,
" both the cavities of the alveoli and the interstitial tissue being infil-
" trated with cells, the intra-alveolar ones being distinguished from the
" others by their greater diameter, and the melanin granules which they
" contained."

Development of lesions resembling those observed after inoculation, in consequence of a surgical operation. Expt. 23.

The last group comprises experiments with melanotic, sarcomatous, cancroid and cancerous products. The most important results were the following. Three rabbits were inoculated with melanotic tumours of the horse. In one of them which died two months and a half after inoculation, a well marked stellate cicatrix was found at the seat of insertion under which a number of nodules varying in size from a millet to a hemp seed were seen. These nodules were ascertained to "consist exclusively of small round cells resembling those of lymphatic glands," enclosed in tough connective tissue. They were regarded by Lebert as structurally identical with tubercles.

Inoculation of various non-inflammatory morbid products. Expts. 24–34.

The two next experiments relate to sarcoma and were without result, excepting in so far that in one of the animals a typical bronchial alveolitis was found. Experiments 33–34 relate to cancroid and carcinoma. They were altogether unsuccessful so far as relates to the communication of cancer, but in one of them appearances resembling tubercle were found in the lungs. Isolated nodules most of which were smaller than pin heads and of a whitish grey colour were found in the lung tissue under the surface of the pleura, the surrounding parenchyma being pale and anæmic. The granulations in the lungs were found to consist of intra-alveolar infiltrations.

In experiments 35–39 charcoal was injected into the jugular vein. In three instances death occurred from the immediate effects of the injection. In the two other cases the charcoal was found to have penetrated to the pulmonary capillaries, liver, and in one case to the brain. In one of the animals which was killed, three months and a half after, when apparently in good health, two small nodular masses of alveolar infiltration were found, each of which contained a little fragment of charcoal in its centre. Several similar fragments were found also in the adventitia of pulmonary arteries. In the other rabbit, which died 24 days after injection, there were disseminated foci of irritation, so numerous, that they occupied four-fifths of the lung. The sections of the infiltrated parts exhibited fine granulations, just like those seen in

Injection of finely pulverized charcoal.

human pneumonia. Microscopic examination showed that the granulations were due to the filling up of the alveoli with a finely granular material containing comparatively few epithelial cells.

In the last six experiments mercury was injected into the veins in five cases, and in one into the trachea. The lesions observed, although of great interest, are not sufficiently relevant to our present inquiry to merit detailed description. In one case, in which death occurred by endocarditis, there was nodular and diffused peri-arteritis, but the alveolar and interstitial tissues of the lung were very slightly involved. Most of the nodules contained quicksilver granules in their centres. Pulmonary suppuration occurred frequently.*

Injection of mercury. Expts. 40–45.

M. Colin's experiments.

M. Colin, in his report to the Academy of Medicine in Paris, on M. Villemin's experiments, relates that in four inoculations made by himself, only one was successful, a result probably attributable to his mode of insertion, which, as he describes it, was certainly ill adapted for the purpose. In subsequent experiments, in which he adopted a better method, the results were nearly as constant as in those of M. Villemin.†

Dr. Roustan's experiments.

Dr. Roustan in his recently published inaugural thesis describes several series of experiments on the inoculation of pulmonary tubercle. In the first series three rabbits were inoculated, one with grey tubercle, one with caseous pneumonia, another with the tissue of tuberculous and softened mesenteric gland. In the second series guinea-pigs were employed. Some of the anatomical results, which are in the main confirmatory of M. Villemin's observations, will be again referred to. In a dog which was twice inoculated, the first time with yellow tubercle, the second time with grey, characteristic tubercular lesions were found in the peritoneum, liver, spleen, supra-renal capsules, and lungs. In another dog, inoculated in the same way, the experiment failed, apparently in consequence of the circumstance that the animal tore out the ligatures with which the inoculation wound was secured, immediately after the operation. In two guinea-pigs in which two grammes of the blood of a phthisical patient were injected under the skin, no result was obtained. In addition to his own experiments, the author relates one important observation made by Dr. Goujon in Professor Robin's laboratory which illustrates the liability of guinea-pigs to spontaneous tubercle, and the rapidity with which the tuberculous lesions are produced by inoculation from animals idiopathically affected. A guinea-pig used for some other experimental purpose was found to have characteristic tubercles in all its organs.‡ Sub-peritonæal granulations of this animal were thereupon inoculated to two others of the same species. One of them died 14 days, the other 18 days after inoculation. In both it was found that the lymphatic glands were enlarged, that the peritonæum was beset with miliary granulations, and that tuberculous nodules existed in the liver, lungs, spleen, and kidneys, which were found on microscopical examination to have the characters of tubercle.§

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* Prof. Lebert and Dr. Oscar Wyss: Beiträge zur Experimental-Pathologie der heerdartigen umschriebenen disseminirten Lungenentzündung, so wie der Uebertragung der sogenannten Tuberculose und anderer entzündlicher und verschiedener neoplastischer Producte von Menschen auf Thiere. Virchows Archiv. Vol. XLI., 1867.

† Colin: Rapport sur deux communications de M. Villemin, ayant pour titre "Cause et Nature de la Tuberculose." Bulletin de l'Acad. de Méd., tome 32, p. 897.

‡ This is the only instance I have met with of the spontaneous occurrence of tuberculous lesions in the guinea-pig, independently of inoculation. Nothing is stated as to the nature of the previous experiments to which these animals were subjected.

§ Dr. A. Roustan, Récherches sur l'Inoculabilité de la Phthisie, Paris, 1867.

Very recently Dr. Waldenburg, to whose anatomical results I shall have to make further reference, has given a short account to the Medical Society of Berlin of experiments made by him on no less than 80 animals (rabbits and guinea-pigs) relating to the inoculability of tubercle. His experiments are divided into five series. In the first of these, miliary tubercles were employed, which were obtained partly from the lungs and pleura, partly from a tuberculous gland, of a phthisical patient. In 16 animals so inoculated, 10 died within a few days after inoculation, and exhibited no traces of tubercular lesion. In the remaining six the lesions were as follows: "In 1 there was a single "miliary nodule in the lungs, and a small miliary focus in the liver. "In 2 numerous miliary foci in the liver. In 3, several miliary foci "in the lungs, and numerous lenticular cheesy alveolar infiltrations "besides pleurisy. In 4 there were numerous miliary foci in the "lungs, and a mass of lobular pneumonia, besides miliary foci in the "liver and kidneys. In 5 there were numerous miliary foci in the "liver and kidneys, while the spleen was enormously enlarged. In 6 "the mesentery was beset with grey and yellow nodules, varying in "size from that of a hemp seed to that of a lentil; the cæcum, and "particularly its appendices, exhibiting the same appearance. Some "of the intestinal nodules projected from the serous surface, others "broke through the mucous membrane and formed little ulcers on its "surface. Peyer's patches contained large ulcers on a caseous base, "some of which were bordered by miliary nodules. The spleen con-"tained a miliary yellow nodule. The kidneys were degenerated and "exhibited minute white foci. The lungs were healthy. The animal "had lived three months and a half, and nothing was to be found at "the seat of insertion."

Dr. Waldenburg's experiments.

The second series relates to inoculations with caseous products. The results were negative. In the third series hypertrophied and cheesy lymphatic glands were employed, which had been removed from a person who was otherwise in good health. Of seven animals so inoculated, four exhibited miliary foci in the liver, and in one there were miliary nodules in the large intestine. In the fourth series pus taken from the inoculation wound of another animal was employed. Of the nine animals two had miliary nodules in the large intestine, one had red hepatisation of the left lung with partial cheesy infiltration of the lower lobe and suppurative pleurisy. In four others there were miliary foci in the liver. In other experiments a great variety of inflammatory products were employed; the results were negative, most of the animals dying very shortly after inoculation.

Subcutaneous insertion of inert matter.

In addition to these inoculations of morbid products, other experiments were made in which materials were introduced under the skin, the effect of which could only be attributed to their mechanical properties. These materials were (1) various tuberculous or other pathological preparations which had been kept four months in spirit, and then steeped in hot water; (2) similar material previously steeped in fuming nitric acid or subjected to prolonged boiling; (3) tuberculous cheesy material intimately rubbed down with aniline blue; (4) aniline blue by itself. In all these experiments the lymphatic glands were enlarged and infiltrated, while miliary nodules were found in the internal organs; when aniline was used, aniline granules could be detected embedded in the nodules. The author states that the structure of these nodules was identical with that of grey tubercle, but the description given is so incomplete that it is not possible to form an opinion upon

No. 6. *On the Communicability of Tubercle by Inoculation, by Dr. Sanderson.*

the subject. It is stated that the research will be shortly published in detail.*

It is finally necessary to notice two series of experiments both of which were entirely unsuccessful, those of Dr. Feltz of Strasburg, and Dr. Vogel of Dorpat. In the first experiments of the former, nine rabbits were inoculated in the usual way with tuberculous matter. In one of the animals seven or eight minute caseous abscesses were found in the lungs, but in the others no lesions of importance were observed. In another series tuberculous matter triturated with distilled water was injected into the jugular veins. Lesions were produced in various internal organs, which, says the author, "at first had the characters of infarcts, and were subsequently transformed into abscesses." He concludes that the nodules which have been regarded by others as tubercles are in reality inflammatory and produced by capillary emboli.†

Dr. Vogel inoculated a crow, a cat, and a pullet, with tubercle taken from a phthisical patient. None of them exhibited the slightest signs of tubercle.‡

SECTION II.—ANATOMICAL RESULTS.

The only detailed or exact anatomical descriptions of the lesions observed in animals inoculated with tuberculous products are those given by Professor Lebert of Breslau, in the two papers already referred to. The accounts given by Villemin refer only to the macroscopical appearances of the alleged tubercles, so that it is not possible to state whether the lesions were always of the same nature, or in what respects they differed from those which we have ourselves observed. But in the minute exactitude and clearness with which Lebert has described his observations, he has given an example which cannot be surpassed.

Subcutaneous lesions; Lebert's results.

Subcutaneous Lesions.§—It will be remembered that in 11 experiments, typical tubercle or pneumonic consolidation around tubercle was employed. In these 11 experiments it was found that in all there were signs of irritation at the seat of inoculation, and that in several instances the local effects were out of proportion with the physical properties of the material introduced and the quantity used. These effects consisted in induration and thickening of the subcutaneous areolar tissue, suppuration of the wound, and the formation of numerous abscesses or foci of suppuration in the neighbourhood. In some instances abscesses were also found at a distance. In one case miliary nodules were found around the wound which are stated to have had all the characters peculiar to tubercle, and to have consisted of rounded partly nucleated cells, which generally varied in diameter from 0·0125 to 0·015 millim., but were sometimes larger. The author regards this as a result altogether exceptional.

Villemin's results.

M. Villemin observed in his inoculations that about a week after the operation a nodosity appears at the seat of the puncture "which communicates to the finger exactly the sensation of indurated chancre." This enlarges progressively, and eventually a little opening forms by which caseous matter

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* Dr. Waldenburg; Die Impfbarkeit der Tuberkulose, Allg. Medicin. Central-Zeitung, 18. Dec., 1867.

† Dr. V. Feltz, Résultats d'Expériences sur l'Inoculation de Matière Tuberculeuse, Gaz. Méd. de Strasbourg, Oct. 25, 1867.

‡ Deutsches Archiv für klinische Medicin, July, 1866.

§ In stating the anatomical results arrived at by Professor Lebert and M. Villemin, the same order will be followed which I have adopted in the description of my own experiments.

escapes. Occasionally the opening closes immediately, the nodule having slightly shrunk, but subsequently reappears again to empty itself after a longer or shorter period. The tumour sometimes attains a considerable volume especially in animals inoculated from others. In cutting through it the section exhibits the aspect of a large tubercle in the subcutaneous cellular tissue. Around the principal mass a certain number of minute yellowish miliary granulations are found which are infiltrated to a considerable distance in the connective intermuscular tissue; sometimes several are agglomerated so as to form nests. The areolar tissue in which these granulations are formed is usually reddened and injected, and occasionally thickened and lardaceous. In structure and development they resemble the tubercles of the lung.

Subcutaneous lymphatic glands; Lebert and Villemin.

Subcutaneous Lymphatic Glands.—Lebert describes two kinds of lesion. In general he observes that the lymphatic glands become enlarged and suppurate. This enlargement and softening to which he applies the term infiltration, appear to him to arise merely from "hyperplasia of the lymphatic cells," and accordingly the products of infection (in the glands) do not conform to any exclusive cell-type, nor constitute a single tissue recognizable by the naked eye. But besides this alteration Lebert finds, in infiltrated or softened glands, "small "yellowish nodules which do not undergo suppuration, and have alto- "gether the characters of the (tubercular) nodules" of the internal organs. Villemin, who elsewhere clearly describes that form of tubercular disease of the lymphatic glands in man which assumes the form of granulation, makes no allusion to its occurrence in inoculated animals. The only alterations he refers to, are enlargement, caseous degeneration, and softening. He adds that the diseased glands are usually connected with the seat of inoculation by a cord of induration.

Pulmonary lesions; Lebert.

Internal organs. Lungs.—The only lesion to which Lebert attaches importance, as affording evidence of tuberculous infection, is that of the formation of disseminated indurations which, although they belong to the tissue of the lung, for the most part occupy a sub-pleural position. These he describes as "infection nodules. They vary in size "from that of a speck (*Pünktchen*) to that of a lentil. . . . They usually "project above the natural and sectional surfaces. . . . Even the very "small nodules appear on close examination to be conglomerates of still "smaller ones. Their consistence is sometimes soft, tenacious (*zäh*), and "gelatinous; sometimes firm and hard. Their colour varies from clear "semi-transparent grey, to dark much pigmented iron grey. Many are "almost opaque, the white or yellowish opacity springing from the "centre. In more rare cases the superficial nodules are surrounded by "a greyish red furrow (*Wall*). The nodules consist entirely of cells, "which, however, are firmly adherent both to each other and to the "neighbouring tissues. The alveolar wall is persistent only in the "smallest nodules. Most of them extend to groups of alveoli, the "arrangement of which groups rather expresses spreading by continuity "than the expansion of an individual lobule; so that the nodules do "not form pencil-shaped appendages to the terminal bronchioles."* The cells are usually round; some contain only fine granules, but others exhibit "a distinct nucleus, on the addition of water, and still more "of dilute acetic acid." Their size varies as above stated. The nuclei "are from 0·006 to 0·01 and even to 0·015 millim. in diameter. The "epithelial type of these cells, with their pale colour, cannot be mis- "taken. They contain either numerous minute opaque granules, or more

* Die Knötchen keines Weges pinselförmig den Endästchen der Bronchien aufsitzen.

" refractive fat granules, or even distinct fat. Pigment is often contained " in them in large quantity, *i.e.*, melanine granules between membrane " and nucleus, in such numbers that the body resembles a pigment cell. " Numerous pale young cells without nuclei, not much larger than blood " corpuscles, are found among the others. Remains of alveoli and elastic " fibres are met with in the masses of cells which mark the spread of the " nodule." In addition to these nodules, which he distinguishes as alveolar, " others are met with, consisting of minute cells with smaller " nuclei, and connective tissue cells mixed with spindle-shaped cells, " both in the alveolar wall, in the bifurcations of minute arteries, and on " the external surface of small bronchioles, sometimes mixed with more " diffuse cell-multiplication of the like microscopical constitution, so " that the infective cell irritation has for its consequences alveolitis, " peri-alveolitis, peri-bronchitis, and peri-arteritis." In injected pre- " parations the alveolar capillaries of the nodules contain no blood. In fine sections of hardened lung, says Lebert, these facts can be still more distinctly recognized; and, in addition, cell-multiplication was observed " in the adventitia of the smallest branches of the pulmonary arteries. " In these proliferations all transitions were seen between diffused " connective tissue, more circumscribed groups, and nodules distinctly " visible to the naked eye." Of the change which gives rise to the central softening of the nodules Lebert gives no detailed account. It appears, indeed, as if in his experiments this process had occurred only to a limited extent. But in a later paper, communicated to the Berlin Weekly Journal (January 6th, 1868), he describes the dissection of a guinea-pig, killed four months and a half after inoculation with peritoneal tubercle, in which the softening of the pulmonary nodules had proceeded to the formation of vomicæ.* Lebert has occasionally observed that general bronchial hyperœmia and mucopurulent secretion from the bronchial membrane occurred, consequently on the formation of nodules, in animals in which they were very numerous. In other cases there were pleural adhesions. M. Villemin gives no anatomical description of the pulmonary lesions.

Hepatic lesions; Lebert.

Liver.—Next to the lungs Lebert found the liver the most frequent seat of " infection nodules." In addition to these, he describes as lesions to be carefully distinguished from them, " small white superficial islands " consisting of fattily degenerated liver cells, which resemble nodules, " and measure from one to two millimètres in breadth, and are as much " as two millimètres in depth." When true nodules occur, he finds that they consist of a semi-transparent material, which has the same appearance as those which occur in the lungs, and that they are associated with a more diffused alteration in the structure of the organ, which he describes as " an inflammatory condition," stating that it consists of " a cell multiplication of the interstitial connective tissue of " the organ, in consequence of which many of its lobules become " atrophied." Of these remarkable lesions only one example, however, is given. It is that of a guinea-pig, which had been inoculated four months and a half previously with firm infiltrated pulmonary tubercle of a patient who had died of phthisis in the third stage. The condition of the liver is described as follows :—" The liver is much enlarged, and " weighs 57 grammes. . . . Its surface is of uniform appearance, and " pinkish grey colour." In several parts there are patches of " irregularly rounded form, which occupy a space of half a square " centimètre, and look as if they were produced by the fusing together

* Since the above was printed, Prof. Lebert has published this observation in detail. See Virchow's Archvi, B. XLI. p. 540.

" of the small white patches," of which many are scattered over the surface. " These deposits are stained intensely yellow with bile, while " their sectional surfaces are yellow, smooth, and glistening." The sectional surfaces of the rest of the organ are also smooth. The true " infection nodules," above referred to, show themselves in such sections as new deposits of a pale red colour verging towards grey, in close apposition to each other; so that the bands of redder and more vascular material by which they are separated from each other do not exceed a millimètre in extent. The consistence of the organ is dense, but it is not so dense as a human cirrhotic liver, which in its external form it resembles. Microscopical sections show that here and there there are groups of liver cells in an unaltered state, among which, however, a few contain minute granules of fat. The rest of the organ consists, in great measure, of " a newly-formed tissue, which is of a pale colour, and " clears on the addition of acetic acid. This tissue exhibits innumerable " minute nuclei of various contours, which lie very close to each other. " The tissue is rich in fibres, which run in all directions; and in con- " sequence of its existence the hepatic lobules in many parts are reduced " in size and atrophied."

Of the alterations in the spleen, Professor Lebert gives no detailed description. In suppurated lymphatic glands he found small nodules of cell proliferation, which closely resembled those found in other organs. The nodules were entirely free from suppuration. More generally the lesion consisted in simple hyperplastic infiltration. Next to the lungs and liver, the lymph glands were the organs most frequently infected.

The inaugural thesis, already quoted, of Dr. Roustan, contains many important and interesting anatomical observations, particularly those relating to the lesions found in the peritonæum in the rabbit, and to the results of his successful inoculation of the dog (see pp. 40 and 48).

Peritonæa. granulations the rabbits.

In one of the rabbits inoculated by Dr. Roustan, which was killed two months after, the existence in the mesentery of grey nodules as large as pin heads, and surrounded by radiating lines of thickening, afforded the only evidence of infection. Each of the smaller of these nodules was found, when examined after hardening in chromic acid, to consist of ovoid nuclear elements; each contained a few fine molecules. The nodules are not distinctly circumscribed, the approximation of the individual corpuscles to each other increasing with their distance from the centre, while many are found separate from the mass in the subserous tissue which surrounds it. Towards the centres of the larger granulations the nuclei are indistinct, being intermixed and obscured by numerous fatty and other molecules.

Tuberculous lesions in the dog.

In the dog the most important results obtained by Dr. Roustan were the following:—The gastro-hepatic omentum was beset with numerous minute granulations, from one to two millimètres in diameter. All of these were found to be in relation with vascular ramifications, each completely surrounding the vessel on which it was situated, just as a bead surrounds the thread on which it is strung. They consisted of rounded or slightly oval nuclei, embedded in a stroma, which was hyaline in the smallest granulations, granular and opaque in the largest. Further, in those parts of the mesentery which appeared healthy, there were " little masses of granulation not visible without the aid of a lens, " which, although they were always found in the course of vessels, " appeared to be altogether independent in their development of the " structural elements of the vascular tissue." On the surface of the liver were numerous granulations, from two to four millimètres in diameter, the structural characters of which were identical with those above described. About a dozen granulations were found in the cortex

of the right kidney, some of which were miliary, others larger and more or less opaque and yellow. Here, as in the rabbit, it was found that the corpuscular growth, constituting the smallest granulations, had its seat and origin in the connective tissue between the convoluted tubes, the epithelium and other structures of which were unaltered. In the lungs two distinct lesions could be made out, viz. (1) subpleural indurations, which, in section, were seen to be due to "abnormal "thickening of the inter-alveolar septa," which in the affected parts appeared to be covered with epithelial cells, closely adherent to each other, so as to form an uninterrupted lining to the air vesicle; and (2) more distinct nodules, which consist partly of "nuclei developed "in the septa, partly of granular epithelium accumulated in the alveolar "cavities."

Section 3, Theories.

We have seen that the accounts given by different observers of the anatomical results of the inoculation of tubercle are remarkably uniform and consistent with each other. But in the interpretation assigned to them no such uniformity is met with. Nor is this in the least to be wondered at if we take into consideration the complicated nature of the questions involved, the novelty of the facts, and their apparent antagonism to those notions about tubercle, which have been hitherto regarded as the teachings of experience.

M. Villemin; reasons for believing that tuberculosis is a zymotic disease.

In giving an account of these theories the precedence is evidently due to M. Villemin, not merely because his experiments were the earliest, but because he is better known in connexion with the subject, at all events in this country, than any other pathologist. His investigation was not undertaken by chance, but in obedience to a conviction previously existing in his mind that *tubercle is a zymotic disease*. To this conviction he had been led by the following considerations; with reference to which it may be remarked that even if the facts on which they are based were indisputable, their bearing on the question is indirect. (1), Tubercle, like the zymotic diseases, is rarely met with in elevated situations; (2), it is most prevalent in crowded populations and especially in great manufacturing and commercial towns; (3), persons who live in common and are confined in their dwellings, such as prisoners, inmates of monastic institutions, &c., are liable to tubercle, while (4), those who live in the open air or lead a nomadic life are comparatively exempt; (5), the frequency of tubercle is greater among soldiers when in barracks, than in armies in the field; (6), those who live with phthisical individuals "in close and ill ventilated dwellings" are apt to become phthisical; (7), phthisis, unknown to certain savage races before their intercourse with Europeans, is now their most destructive scourge; (8), bovine phthisis prevails most among animals that are confined and overcrowded; (9), the antagonism between phthisis and malaria may be explained on the ground that malarious countries are sparsely inhabited; (10), the contagiousness of phthisis has always been matter of common belief; (11), in its development phthisis resembles several of the zymotic maladies. Thus (a) it resembles typhoid fever so closely that it is often indistinguishable from it, the resemblance extending not only to the phenomena observed during life but to the anatomical lesions, which in both diseases have their principal seat in the lymphatic system. The causes which produce them, and the ages at which individuals are most liable to be attacked, are similar. (b.) The likeness of tubercle to farcy is still more striking. In the latter the essential lesion consists in the development of granulations, anatomically

identical with those of tubercle, which have their seat more frequently in the lungs than in any other internal organ, and in both diseases the lymphatic glands undergo enlargement, induration, and caseous degeneration. The etiological relations of the two are the same, while the symptoms are so much alike that it is scarcely possible to point out any differences excepting such as arise directly from the specific differences of the animals affected.*

From all these considerations Villemin inferred that tubercle is not merely a form of perverted nutrition, but a specific disease, one in its essence, however various in its manifestations, and that its cause must be a specific infective material capable of transmission from the diseased to the healthy body, and endowed with the faculty of multiplying itself therein so as to reproduce all the original phenomena. Of the truth of this inference he regards the inoculation experiments as proof. "Tuberculosis can be compared only to the virulent diseases . . . "How the tuberculous virus engenders tubercle we can no more explain "than we can how the syphilitic virus produces secondary syphilis. "The proof of the existence of this morbid principle consists in the fact "of successful inoculation . . . Every morbid material is a virus "which when introduced into the organism in small quantities, deter- "mines lesions which are constant in their character, and can be "shown to exist after the lapse of a certain time in different and remote "parts of the body in increased quantity," and this definition he holds to be fully applicable to tuberculous matter.†

Mr. Simon's verification.

Mr. Simon, when communicating to the Pathological Society his verification of M. Villemin's experiments, did not offer any theory of the facts, but was careful to state that his "testimony to the genuineness of "the very important pathological discovery which M. Villemin claims "to have made" must be understood to be "subject to such qualifica- "tions as an amended pathological definition of 'tubercle' may hereafter "render necessary.

Professor Lebert's first views.

From Villemin let us turn to the learned and laborious professor of Breslau. In concluding his first paper, Professor Lebert says that his own results and those of Villemin prove that in tuberculosis just as in smallpox, syphilis, and farcy, we have to do not with a simple inflammatory process which spreads *de proche en proche*, but with a special element belonging exclusively to tuberculous disease. This opinion is, however, expressed with great caution, for says Lebert, "the experimental investigation of the subject is as yet scarcely begun." Any modification of the current etiological doctrines of organic diseases should be received "with the utmost reserve and under the control of a criticism as sober as it is severe."‡ In his second paper the author displays still greater unwillingness to dogmatise, so that his opinions have to be gathered from such expressions as are scattered here and there throughout his communications. So far as they relate to the most important aspects of the question, viz., the significance of the lesions and the nature of the process by which they are produced, the following passages show that Lebert's present views are in great measure opposed to those expressed in his earlier paper. As regards the significance of the lesions he admits that the condition of the lung observed in inoculated animals

His more recent conclusions.

* M. Villemin points out, that the fact that the two diseases are antagonistic is no argument against their analogy, any more than the antagonism of vaccination to smallpox would afford ground for denying the close alliance which exists between the latter and cowpox.

† Villemin, loc. cit., p. 589.

‡ Bulletin de l'Acad. de Med., tom. 32, p. 151.

Relation between the tuberculous and the inflammatory processes.

is anatomically identical with that which exists in disseminated chronic pneumonia and in acute tuberculosis, but is entirely unwilling to regard the formation of nodules in the lung or elsewhere as constituting *new growth*, the very nature of which he repudiates in the strongest terms.* In short he finds it altogether impossible either to define what tubercle is or to state what are the limits which separate between it and the products of inflammation, and he regards "the whole doctrine " of tubercle as governed by inflammation, an inflammation of which " the development is the more rapid, the more unfavourable is the con- " dition of nutrition of the whole body, and of the affected tissue in " particular, while its progress is accelerated by the absorption of " pathological products or of materials produced by their decomposition. " The minute granulations which we recognize as tubercle are usually " produced by the transportation and dissemination of the products of " an undoubted primary inflammation, which itself may exhibit all " transitions between small granular nodules and extensive infiltrations, " and they are as much localized in the tissues belonging to the type of " the connective tissue as in the epithelial tissues. True tubercular " granulation is therefore closely allied to the inflammatory processes " from which it has originated, and of which, indeed, it is the product." This appears not only from their development, from the mode of extension of the granulations, and from their relation to surrounding parts, but from the characters of the more diffused cell-proliferations which take place in their neighbourhood.†

Prof. Lebert's explanation of the effects of inoculation.

As regards the mode in which the infection takes place, Lebert considers the influence exerted by inoculation as probably partly chemical, partly mechanical. A purely mechanical stimulus appears to him insufficient to explain the facts; "the existence of a purely chemical one " is not proved, and certainly would be difficult to prove, so that it is " only by exclusion that we can judge how much of the observed effect " ought to be provisionally assigned to chemical stimulation, as being " inexplicable mechanically.‡ He thinks it probable that at the point of inoculation "an infective fluid is formed from the material inoculated " and from the products of inoculation, which, conveyed through the " lymphatic and sanguiferous blood vessels, enters into corpuscular " combinations" (in the blood?) "and so produces stimulation and ob- " struction. The conveyance of material by the lymphatics produces " stimulation and proliferation of cells in the lymphatic glands, mani- " festing itself either in infiltration or granulation. . . . But it is " through the blood vessels that the organism is more thoroughly and " deeply infected. Infective material in a broken down, more or less " emulsive condition, or secondary inflammatory products, are absorbed " by the capillaries. . . . All these elements pass without difficulty " through the venous trunks, and probably undergo corpuscular trans- " formation. . . . Having arrived at the right auricle the carriers " of infection [which Lebert thinks are probably cells newly formed in " the blood] pass into the lungs and for the most part stop up the " capillaries like little emboli. Others, however, go through, and so " find their way to the left side of the heart and the systemic circula " tion. For the most part they miss the openings of the ascending " arteries . . . so that the greater number pass into the descending

* " Ein jeder fühlt sogleich wohin eine so extravagante Begriffs-Erweiterung und Verwirrung führen würde," loc. cit., p. 564

† The above sentences are rather freely translated, the peculiarities of Prof. Lebert's style being such that a literal rendering would be unintelligible.

‡ Lebert, loc. cit., p. 576.

" aorta, and thence into the cœliac axis, whence it happens that the " liver and spleen are much more frequently infected than the kidneys."

" How then does the infection take place? . . . In all probability " the general laws of cell stimulation and proliferation have much more " to do with it than specific peculiarities of the infective juice; for it " is to be observed that the same cells are stimulated to proliferation by " agents of different nature, and on the other hand that the same agent " stimulates different types of cells; in fact the several cells show no " differences of type excepting such as may be accounted for as different " stages of progressive and retrogressive metamorphosis. Similarly " the products of the disintegration of primary granulation or infiltration " become new centres of infection, the influence of which radiates and " extends to more distant parts, so that the infective material may " increase very considerably in the organism." To explain this secondary process as purely mechanical, Lebert regards as "not unphysio- " logical; but the connection of the secondary foci with the primary " focus can only be explained by admitting the existence of a special " tendency, perhaps a special element of transmission. But let us " beware," he continues, " of identifying the inflammatory infection " with which we are now occupied with neoplastic or heteroplastic " infections, such as cancer, cancroid, &c."*

In the preceding paragraphs I have endeavoured to bring together Professor Lebert's opinions in such a manner as to render them intelligible. In reading his paper one cannot help regretting that he has allowed his views of the nature of the tuberculous process to be so powerfully influenced by his conviction of its inflammatory nature.† In spite of his determination to refer everything to non-specific tissue stimulation, he is obliged again and again to admit that other influences are at work, but does not seem to see that in yielding so much he yields all. Once allow that the stimulus is chemical as well as mechanical, "specificity" can no longer be excluded; for clearly if the effect is chemical the agent must be a specific substance, a proximate principle, for chemistry does not recognize "tendencies." To admit that there is a "*besonderes Element der Uebertragung*" in the blood, and at the same time to deny specificity implies that he who does so, uses the word in a very peculiar sense.

Views of M. Colin.

M. G. Colin, to whom the communications of M. Villemin to the Academy of Medicine in Paris were referred for a report, admits that the experiments made by him prove that tubercle is a contagious disease, but refuses to entertain his conclusions as to its dependence on a specific virus. He regards the whole process as purely mechanical, attributing the lesions to the reception of morbid products into the lymphatic vessels, not by absorption through their walls, but by the "open mouths of wounded capillaries and lymphatics." The course which the infective material follows may be easily traced, especially when pus is mixed with the tuberculous matter, by the engorgement of the lymphatic vessels and the enlargement of the glands. Its progress is so slow that it is not until several weeks have elapsed that it arrives at its destination in the internal organs, where it assumes the form of little masses (*umas*), evidently regarded by M. Colin as products of local inflammation.

Views of M. Chauffard.

In the discussion of M. Colin's report which took place on the 15th of last October, M. Chauffard, in a speech of great length, compared

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* Lebert, loc. cit., p. 578.

† "Für uns dominirt die Entzündung die ganze Lehre der Tuberculose," loc. cit.

the effect of inoculation to the fecundation of one tissue by the contact of elements emanating from another, the fecundated tissue being thereby caused to produce histological elements not resembling its own but those of the fecundating tissue. The proliferation which occurs in the affected organs is due according to M. Chauffard to a stimulation of their structural elements, which is strictly local and altogether independent of any general morbid infection or virus. This local stimulation shows itself more especially in the lymphatic glands, the tissue of which may in fact be regarded as the "matrix destined to be fecundated." It is towards them that the tuberculous matter is conveyed by the lymphatics; "the histological elements of which they consist (lymphatic cells or corpuscles) are so nearly allied to those of tubercular granulations, that most of the German pathologists have regarded them as identical, and have considered tuberculous granulation in general as a heterotopical formation of normal lymphatic elements." Like M. Colin, M. Chauffard regards Villemin's experiments as having no bearing whatever on the specificity of tubercle; but he declines to follow M. Colin in his opinion that tuberculosis is contagious. Willingly admitting that the local disease is in reality tuberculous proliferation, and that the disseminated nodules in the lungs and other organs are tubercles, he denies that "the general affection known under the name of tuberculosis" is really communicated to the inoculated animal.

Views of Dr. Waldenburg.

Dr. Waldenburg holds that the process induced by inoculation consists in the intussusception of finely divided particles, smaller, or at all events not larger than blood corpuscles, and in their being deposited in various organs. These particles becoming lodged in the capillaries of internal organs, finally escape out of the circulation by penetrating the vascular wall, in which escape he thinks it possible that they may be accompanied by colourless blood corpuscles, and thus originate miliary granulations in the neighbourhood of the vessels.* He thus holds a position nearly identical with that of M. Colin, although his views are much more clearly and definitely expressed. He regards them as applicable not only to the results of inoculation, but to the development of human tubercle, and thinks that clinical experience justifies the conclusion that in man as in inoculated animals, miliary tubercle is produced in the tissues of affected organs by the deposit of extremely fine particles previously received into the blood-vessels. At the same time he admits that this mechanical process does not constitute the essence of tuberculosis, for without reference to the facts which show phthisis to be a diathetic disease, its hereditary transmission can scarcely be explained unless it be granted that it consists of something more than anatomical lesions. Like Professor Lebert Dr. Waldenburg expresses himself with great caution, and conceals from himself and from his readers his belief in what other people designate the tubercular diathesis, by speaking of an "hereditary susceptibility to stimulation," and so forth.

Summary.

From the preceding summary of the views entertained by the principal pathologists who have directed their attention to the subject, it will be seen how numerous are the aspects in which the results of tubercle inoculation may be regarded, and how complicated are the questions which arise out of them. It is important, however, to notice that in so great a diversity of opinion there are certain particulars in respect of which all are agreed. Thus it is generally admitted that the certain result of the inoculation of tuberculous matter of whatever kind is to produce crops

* Dr. Waldenburg considers that the researches of Cohnheim have demonstrated the possibility of the escape of blood corpuscles from the capillaries, independently of rupture.

of miliary granulations in the lungs and other internal organs; that these granulations are anatomically identical with grey tubercle, that they become yellow and opaque, and eventually break down into a soft cheesy material. It is further admitted on all hands that the process is, so to speak, a self-diffusive one, that in the act of inoculation a new element is introduced into the inoculated animal at the point of insertion, from which it is disseminated to all parts of the body through the lymphatic and arterial circulation.

At this point agreement ceases. It is neither agreed what the new element is, nor what is the nature of its effect on the blood, or on the living tissues to which the blood-stream carries it. With reference to these questions we find three views indicated. They may be expressed as follows: (1.) The material introduced consists of microscopical particles, possessed of no properties excepting those they owe to their hardness, form, and magnitude, and therefore capable of producing no effects excepting those of mechanical irritation. (2.) The material consists of living matter, capable either of growth by assimilation of new matter similar to itself, or of causing morbid transformations in the tissues with which it comes into contact; in either case acting in a specific way which cannot be referred to its physical properties. (3.) It is a definite chemical compound which is soluble in the blood plasma, and has a special and exclusive action on certain tissues, particularly that of the lymphatic glands and other analogous structures.

Practically, the first and second of these propositions are the only important ones; for, although Professor Lebert has suggested the co-operation of a chemical with a mechanical action, he has given no explanation of his meaning. That it is possible to conceive of such an agent as is described in the third proposition can scarcely be disputed, but the extremely small quantity of the material used, taken together with the postponement and protracted duration of the results, are facts of which no intelligible chemical explanation can be given, so that the issue may be narrowed, so far as relates to the origin of the morbid process, within the limits indicated in propositions 1 and 2. If, on the one hand, the lesions can be fully accounted for by the entrance of minute particles of hard, but absolutely insoluble and innocuous material into the arterial circulation, we are bound to accept this explanation as the simplest, and to admit with Prof. Lebert that the granulations are merely circumscribed inflammations. If, on the other hand, none of the effects can be explained on this mechanical principle, little seems to be left to us but to admit that the contagium of tubercle acts in the same way as the contagia of the so-called specific diseases. Lastly, if the distribution of the granulations and their similarity to those produced mechanically, should seem to suggest that their mode of origin may be mechanical, while other influences manifest themselves in their development, we are perfectly at liberty to adopt the mechanical explanation, so far as it goes, and to supplement it with such other explanations as the facts may warrant.

Postscript.—(March 31.)—Observations which I have had the opportunity of completing since this report was in type, afford evidence of so important a character in support of some of the conclusions embodied in it, that I gladly avail myself of the opportunity which has been afforded me of adding the results.

It has been found that if animals are inoculated with pus derived from the secondary abscesses of patients affected with pyæmia, death is apt to occur during the third or fourth week after inoculation, in which case the results of dissection is as follows:—Abscesses are found at the seat of inoculation, and purulent deposits in the neighbouring subcutaneous tissue; these, although obviously of the same character as those observed after inoculation of tubercle, differ from them in being larger, more numerous, and more generally distributed. The subcutaneuos lymphatic glands are healthy, or at most a little enlarged. The internal organs are usually free from disease. When this is not the case, lesions of an obviously inflammatory nature are found; as for example, pleuropneumonia, pericarditis, or subpleural or subperitoneal abscesses. If, on the other hand, the animals survive the primary, *i.e.* hyæmic, effects of which these lesions are the expression, and are examined several months after inoculation, morbid appearances are found in the lungs, liver and spleen, in which all the anatomical pcaracters of a tuberculous process are to be recognized.

From these facts it is evident that these lesions can no longer be regarded as dependent on any property or action possessed by the inoculated material in virtue of its having been taken from the diseased organs of a phthisical patient. This conclusion is rendered almost certain by the result of the following experiment. On the 29th of October last, setons of unbleached cotton were inserted, by means of a needle which had not been used before, in the shoulders of two guinea-pigs, which from their being entirely white could be easily distinguished from any of the other animals under observation, all of which happened to have spots of colour. One of these animals was killed on the 28th of December, and was dissected by Mr. Simon and myself. One of the setons was surrounded by a hard mass of semi-transparent substance—obviously dried-up pus, which was surrounded by connective-tissue induration. The other abscess was of considerable size; the material contained in it was of the consistence of cream cheese, and on microscopical examination the corpuscles of which it consisted were found to have the characters represented in Plate I., fig. 9 (see description). The internal organs were perfectly healthy. The other animal died on the 15th of March. There were two open wounds on the left shoulder, each of which led to a sinuous cavity, containing a small quantity of pus, the greater part of the contents of the abscesses having escaped externally. Both cavities were connected with each other and with the neighbouring scapular gland, which was enlarged and softened, by subcutaneous bands of induration, and there were numerous purulent deposits in the neighbouring muscles and areolar tissue. The lungs contained very numerous iron-grey nodules. The liver was much enlarged, and presented the characteristic appearances of interstitial adenoid deposit. In the spleen there were numerous miliary nodules. There was enlargement of the agminate glands both of the large and small intestines, as well as of the lymphatic glands in the gastrohepatic omentum and mesentery. In this case, therefore, a pathological process which had originated in traumatic subcutaneous suppuration resulted in lesions which were characteristically tuberculous.

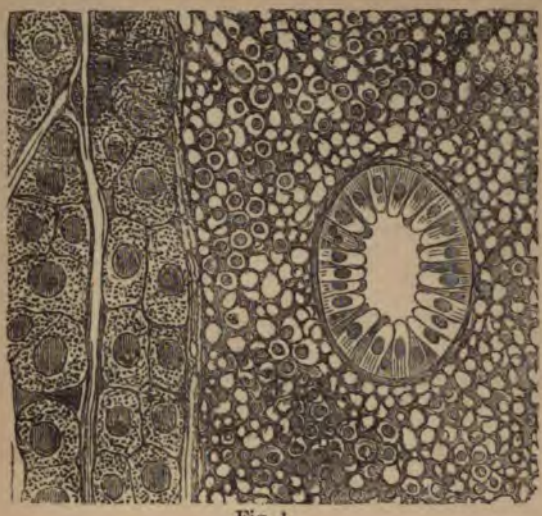

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

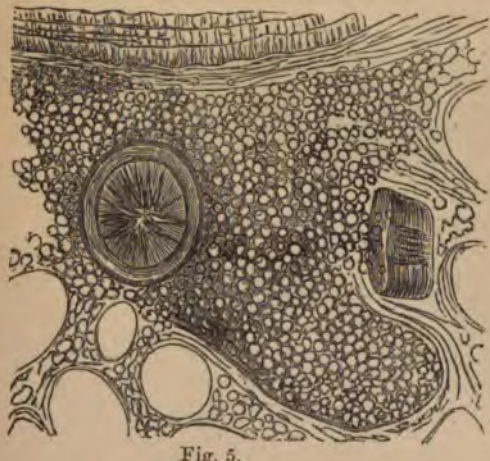

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

EXPLANATION OF THE PLATE.

FIG. 1.—Section of diseased tissue of the liver. In the middle of the drawing is seen a bile-duct lined with epithelium, about $\frac{1}{100}$ inch in diameter, which is cut across obliquely. The duct is surrounded by adenoid tissue, the nuclei of which appear to be contained in the cavities of a transparent loculous stroma. To the left this tissue is separated by a well defined border from the liver cells, which are arranged in oblong masses, between which there are capillary blood vessels.

FIG. 2.—Section of a superficial miliary nodule in the spleen. The natural surface is cut through vertically. Towards the upper part of the drawing, where the tissue is nearly healthy, the nuclei are larger, and many of them look as if enclosed in cells. Near the surface they are smaller and more numerous, so that the loculi appear to be choked with them. This multiplication seems to constitute the only difference between diseased and healthy parts.

FIG. 3.—Section of healthy lung; the pleural surface is cut across vertically.

FIG. 4.—Vertical section of the wall of a minute subcutaneous abscess. Nearest the cavity of the abscess its wall is seen to consist of closely packed corpuscles, some of which, larger than the rest, resemble pus-corpuscles. At a short distance from the surface the corpuscles are arranged in oblong heaps, which lie in a faintly fibrillated stroma. Still further there are numerous staff-shaped nuclei, not distinguishable from those of the surrounding indurated connective tissue.

FIG. 5.—Peribronchial granulation of lung. At the lower part of the drawing is seen a bronchial tube cut across. It is surrounded on all sides by an accumulation of spheroidal corpuscles, which constitute the kernel of the granulation. The walls of the neighbouring alveoli are thickened. Above is seen a portion of an artery (dislocated in the section, so that it lies on its side), and to the left another artery, which is much smaller. Each is surrounded by its adventitia, the structure of which appears to be unaltered.

FIG 6.—Section of iron-grey induration of lung. The pleural surface is cut through vertically. The alveolar cavities are completely filled with nests of large nucleated cells, most of which contain pigment granules. The alveolar tissue is only slightly altered.

FIG. 7.—Creamy pus from a subcutaneous abscess. The smaller spherical corpuscles resemble those of normal human pus. The larger ones have the characters of glomeruli, and are scarcely affected by dilute acetic acid.

FIG. 8.—Action of acetic acid on the smaller corpuscles.

FIG. 9.—Pus corpuscles from a caseous abscess. When acted on by acetic acid, their outline becomes more defined, but their appearance is otherwise unaltered.

FIG. 10.—Cretaceous granules from nodules in the spleen.

TABLE OF MEASUREMENTS.

	Diameters.
Subcutaneous tissue:	
Spheroidal nuclei of indurated connective tissue	$\frac{1}{4100}$ — $\frac{1}{3500}$ inch.
Spheroidal corpuscles of pyogenic membrane (see Fig. 4)	$\frac{1}{2800}$
Pus corpuscles (see Fig. 7)	$\frac{1}{2000}$
Glomeruli	$\frac{1}{1000}$
Lungs:	
Spherical corpuscles of granulations (see Fig. 5)	$\frac{1}{4400}$ — $\frac{1}{3300}$
Nuclei of inter-alveolar thickening, about	$\frac{1}{2800}$
Nuclei of intra-alveolar cells (Fig. 6)	$\frac{1}{2500}$ — $\frac{1}{2000}$
Intra-alveolar cells	$\frac{1}{1400}$ — $\frac{1}{1000}$
Liver:	
Nuclei of adenoid growth	$\frac{1}{5500}$ — $\frac{1}{4500}$
Nuclei of liver-cells	$\frac{1}{3000}$ — $\frac{1}{2400}$
Spleen:	
Nuclei near surface in section represented in Fig. 2.	$\frac{1}{4100}$ — $\frac{1}{3500}$
Nuclei further from surface in the same section	$\frac{1}{2800}$ — $\frac{1}{2400}$
Peritonæum:	
Nuclei, mostly oval, constituting perivascular granulations in omentum	$\frac{1}{2800}$ — $\frac{1}{2500}$
Occasionally much larger nuclei are seen, not less than	$\frac{1}{1800}$

No. 7.—DR. THUDICHUM'S REPORT (chiefly introductory) on RESEARCHES intended to promote an improved CHEMICAL IDENTIFICATION of DISEASES.

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I.—RELATIONS OF THE SUBJECT TO GENERAL CHEMISTRY.

Objects of researches.

The broad object of the researches to be reported on in the following pages is to advance the knowledge of disease by such new chemical information as may be established with certainty. Mere quantity of result is regarded as of secondary importance; and if, nevertheless, the researches should appear to spread over a very large area, it must be remembered that none claim to be considered complete which are not expressly put forth as such. And the method upon which all the researches are conducted is to be judged only from the finished portions; it being implied that a similar completion is to be given in the future to subjects appearing at present only in outline. Of finished portions, the essays "on cholophæine," "on biliverdine," and "on uromelanine," may be quoted, of which abstracts will presently be given, and which were presented *in extenso* to the Royal Society by the Medical Officer. The whole of my method may further be seen, applied hurriedly, owing to the rapidity of the epidemic and external difficulties, in the "Chemical Researches on Cholera," published in the annual report of the Medical Officer for 1867.

Difficulty of separating physiol. and pathol. research.

It has been found impossible to exclude physiological research, although the final aim is pathological information. The chemist in general mainly cares for isolation and characterisation of *well-defined substances*. Having in a research found enough of these to reward his intention, he would generally neglect the residues. Owing to this practice, quite natural on the part of chemists, a great part of the constituents of the body is at present unknown, or imperfectly known. Thus the brain yields cerebric acid, but contains also a large bulk of a peculiar compound, which if able to yield cerebric acid, is a complicated compound of this matter with other unknown substances. This peculiar compound is neglected by all chemists who have ever made inquiries on the brain; the pathological chemist is, however, called upon to deal with it, as he cannot form any conception of pathological processes of the brain matter before knowing the chemical constitution of the

whole. Again, of the watery extract of muscles only one-sixth is defined, five-sixths are undefined. It would be impossible to judge of muscular affections, be they direct and local, or indirect and effected by nerve-lesions, without a knowledge of these at present undefined matters. They have therefore to be studied, as chemists in search merely of defined bodies would not turn their attention to ungrateful, difficult, and expensive researches.

Difficult objects of physiol. research.

Physiological chemistry experiences its main difficulty in the changeable nature of its objects. Latterly another has been added to our knowledge which is almost stupendous in character. It is the extremely high atomic weight of the main ingredients of the body; a weight, which in the red-coloured ingredient of the blood rises to 13,000, and in the brain probably much higher. Ordinary organic chemistry deals with comparatively simple substances, in which the atomic weights do not exceed as many tens as in the physiological molecules before mentioned there are thousands. The fact that synthetic chemists can imitate some simple organic compounds must, when these immensely complex molecules are remembered, cease to be matter for very great boast. And the same knowledge has had a corrective influence upon a much more important part of our philosophy. We believed that the plant only was synthetical, that the animal merely applied what the plant had previously prepared. This however is not the case. True, in seeds there is even cerebric acid (or some body very much like it) as well as in yelks and brains. But in neither there is brain-matter. In yelks there is the capability for the production of blood, but not blood itself; in seeds there is no blood, and no capability for forming it; hematocrystalline is the product of the synthetical activity of the animal economy. Both plants and animals, therefore, are chemically constructive, but the animals build with the materials previously prepared by plants; plants construct from inorganic food, animals from the organic food offered by plants or other animals; and the molecules which animals construct surpass in complication and number of atoms any which plants produce.

Intricacy of problems of pathological chemistry.

Far more intricate is the problem of pathological chemistry. It deals with the deviations of these substances which are infinitely complicated, one penetrating the other. It deals with processes which (so far as we know them) are ever tending to become normal, and which (if they do not kill) terminate in definite times. The objects of the research occur for the most part only accidentally, fitfully, with all sorts of admixture, and not at such times and places so as to favour investigation. If physiology seeks a definition of life, pathology is held to aid in this search and the search after the nature of disease at the same time. And if it were only an inquiry after the destructive nature of disease it might appear simple; but the problem has a physiology of its own, it is synthetical as well as life, for morbid growths must be considered syntheses.

Disease obeys natural laws.

The processes and products of disease obey the same general natural laws as all other processes and matters, and in addition the laws of their special causation. Carbon in the smallpox-pustule remains carbon, and subject to the laws under which that element exhibits its various properties; but it deviates in function for a while by the agency of a special interfering cause. In the case of small-pox this cause is probably physical, but in other diseases, such as paralysis from terror, cannot be so. In a complete system of etiology all manner of causes have to be considered; but in pathological chemistry, only such causes as are chemical. Therewith all chemical effects from any causes whatever, come under consideration.

Definition of pathological chemistry.

I define pathological chemistry as the science of the deviation of atoms

from their normal function. Ultimate pathology cannot, I think, be cellular, as was claimed by Virchow, or molecular, as was at one time taught by Hughes Bennett and Beale, but can only be atomic; and if a further subdivision of matter in power and place going beyond the atom should become possible, then pathology must still be atomic before it can be considered by the light of the more expanded theory.

Although the definitions of the chemical terms used in pathological chemistry do not differ from those used in general chemistry (as far as the subjects are identical), yet it may be useful in this place to shortly summarise these terms and definitions, as they occur repeatedly in the sequel. Moreover, there have lately been changes in and additions to the doctrines concerning atoms and their symbols, and relative weights, and powers; and these it is well to state, in order to avoid the confusion which their use without explanation might cause even to persons well versed in the chemistry of the equivalential period.

Element. We define "element" as matter which appears to be chemically homogeneous, *i.e.*, which by no chemical means can be separated into two chemically heterogeneous matters. The idea of element therefore precedes that of atom, and the idea of atom in the chemical sense can

Atom. only exist after the admission of the definition of element. An "atom" is the smallest quantity of an element which can exist in any chemical combination. And further, it can exist only in combination, and not by itself in the free state. The atom has powers which must be satisfied, and if it is prevented from existing in combination with heterogeneous elements, it combines with at least one atom of its own kind or element differing from it only in quality (polarity) of power. Such a combination of two atoms is the type of a molecule, and the smallest *possible* molecule. A molecule can exist by itself or react upon others. It may consist of two atoms or any number of atoms (up to 1,895, see blood) and the limits up to which the number of atoms in molecules

Molecule. may increase are at present unknown. "Molecule" we define as the smallest quantity of an element or compound which may exist in the free state or enter or leave a combination.

Chemism. Polarity. All atoms possess chemism, polarity, and dynamicity. "Chemism" is the liability, or the cause of the liability of matter to undergo interchange, movement or combination, and to transform into chemical movement such physical influences as those of sunlight. "Polarity" on the other hand determines the relative place of each atom in the forthcoming combination, and thus fixes the molecule. Let us assume the existence in a molecule of hydrogen of two atoms of hydrogen, having, the one + or positive, the other negative or —, polarity. This plus and minus is to signify that the polarities are heterogeneous, and capable of neutralising each other by combination. Let us express the molecule of hydrogen by the formula $\overset{+}{H}\ \overset{-}{H}$. If now to this molecule we bring a molecule of another element possessing the necessary chemism, *e.g.*, chlorine, and similar polarities of atoms, $\overset{+}{Cl}\ \overset{-}{Cl}$, then a combination by interchange will take place, and two molecules, having equal elements, of hydrochloric acid, namely $\overset{+}{H}\ \overset{-}{Cl}$ and $\overset{-}{H}\ \overset{+}{Cl}$, will be produced; but these molecules will have unequal properties in as far as the polarity of their elements is concerned; for the one will have plus or positive hydrogen $\overset{+}{H}$ and negative chlorine $\overset{-}{Cl}$, while the other will have negative hydrogen $\overset{-}{H}$ and positive chlorine $\overset{+}{Cl}$. However slightly these differences may affect the ultimate products in their grosser properties, they are real and have to be borne in mind in all higher chemical

considerations.*] The "dynamicity" of a given atom is the varying quantity of its combining-power under varying conditions:—for instance, the atom of iodine is monodynamic in hydriodic acid, where it combines with a single atom of monodynamic hydrogen; tridynamic in terchloride of iodine, where it combines with three monodynamic atoms of chlorine. The "dynamis" is exerciseable in multiple directions, but not separable as to seat. The unit or minimum of dynamis manifested by an atom is a "monad." The maximum dynamis which can be manifested by an atom is atomic power, and as this is ascertained by relative weight it is termed "atomic weight." The quantities expressing the atomic weights have been derived from the circumstance that elements combine in certain proportions of unchangeable weights, or of simple multiples of those weights, and that these weights stand in a certain proportion to the volume which bodies (which are capable of existing as gases) maintain in their gaseous condition. An atom of hydrogen occupies one volume, a molecule occupies two. An atom of chlorine occupies one volume, a molecule two. The atom or volume of hydrogen is much lighter than the atom or volume of chlorine, weighing 1, while the latter weighs 35·5. By the combination of these two molecules two fresh molecules of hydrochloric acid are produced. These occupy the same volume as the uncombined gases previously did. The definition of molecule as two volumes of a compound of a gaseous body leads to the knowledge of the condensation which elements have undergone during the process of combination, and by all other considerations of the properties of atoms, and of the specific heats of elements, to the knowledge of the atomic weights. These as lately determined differ from the former equivalents by the fact that many have been doubled. They are distinguished in their symbols by a horizontal bar, thus $\bar{C}$, standing across the middle of the letter. As many of these symbols have to be used in the sequel, I here give a list of them, together with the dynamicities and atomic weights of the elements.

Dynamicity.

Monad.

Atomic weight.

Names.	Symbols.	Dynamicities.	Atom. weights.
Aluminium	$\bar{Al}$	III. VI.	27·5
Antimony	Sb	III. V.	122·
Arsenic	As	III. V.	75·
Barium	$\bar{Ba}$	II.	137·
Beryllium	Be	III.	14·
Bismuth	Bi	III.	208·
Boron	Bo	III.	11·
Bromine	Br	I.	80·
Cadmium	$\bar{Cd}$	II.	112·
Caesium	Cs	I.	133·
Calcium	$\bar{Ca}$	II.	40·
Carbon	$\bar{C}$	IV.	12·
Cerium	$\bar{Ce}$	II.	92·

* The lactic acid of milk differs from the lactic acid of flesh, not in composition but unimportant collateral properties. There are several turpentines distinguishable only by different influence on the polarised ray of light. These may possibly differ from each other only by some such peculiar disposition of subordinate power (polarity) as is illustrated in the above example.

Names.	Symbols.	Dynamiciti (?)	Atom. weights.
Chlorine	Cl	I.	35·5
Chromium	Cr	III. VI.	52·5
Cobalt	Co	II.	58·8
Copper	Cu	II.	63·5
Didymium	Di	II.	96·
Erbium	Er	II.	112·6
Fluorine	Fl	I.	19·
Glucinum	G	II.	9·
Gold	Au	III.	196·7
Hydrogen	H	I.	1·
Iodine	I	I. III.	127·
Iridium	Ir	II. IV.	198·
Iron	Fe	II. VI.	56·
Lanthanium	La	II.	92·
Lead	Pb	II. IV.	207·
Lithium	Li	I.	7·
Magnesium	Mg	II.	24·
Manganese	Mn	II. VI.	55·
Mercury	Hg	II.	200·
Molybdenum	Mo	VI.	92·
Nickel	Ni	II.	58·8
Niobium	Nb	IV.	97·6
Nitrogen	N	I. II. III. V.	14·
Osmium	Os	IV.	199·
Oxygen	O	II.	16·
Palladium	Pd	II.	106·5
Phosphorus	P	III. V.	31·
Platinum	Pt	II. IV.	197·4
Potassium	K	I.	39·
Rhodium	Rh	II.	104·
Rubidium	Rb	I.	85·5
Ruthenium	Ru	IV.	104·
Selenium	Se	II.	79·
Silicium	Si	IV.	28·5
Silver	Ag	I.	108·
Sodium	Na	I.	23·
Strontium	Sr	II.	87·5
Sulphur	S	II.	32·
Tantalum	Ta	IV.	137·5
Tellurium	Te	II.	128·
Thallium	Tl	I.	204·
Thorium	Th	IV.	231·3

Names.	Symbols.	Dynamicities.	Atom. weights.
Tin - - - -	~~Sn~~	IV.	118·
Titanium - - -	~~Ti~~	IV.	50·
Tungsten - - -	~~W~~	VI.	184·
Uranium - - -	~~U~~	II. III. VI.	120·
Vanadium - - -	V	II. V.	51·2
Yttrium - - -	~~Y~~	II.	68·
Zinc - - - -	~~Zn~~	II.	65·
Zirconium - - -	~~Zr~~	IV.	90·

The foregoing system is in harmony with all other facts, chemical or physical, concerning elements, because the atomic weights are, with three exceptions,* the same as those derived from the law of Dulong and Petit, which is to the effect that the specific heats of elements multiplied by their atomic weights give the same product. If we term this product "atomic heat," we may say that these elements possess the same atomic heat. Further, the atomic heats of a great number of compounds are equal to the sums of the atomic heats of their elements. A second great reason for the adoption of the new atomic weights is, that they are in harmony with the law of isomorphism (Mitscherlich); and a third, that they are in harmony with the relations existing between the density of the gases and vapours and their molecular weights: that is to say, the densities of the simple gases stand in the same proportion to each other as their atomic weights, or, hydrogen being accepted as the unit or = 1, the figures expressing the densities of the other gases compared to hydrogen as 1, are the same as those expressing their atomic weights (Gay-Lussac). This led to the law of Ampère and Berzelius, according to which equal volumes of simple gas contain equal numbers of atoms †; and to the further development of that law that equal volumes of gas contain equal numbers of molecules, and, consequently, that the molecular weights of compounds are proportioned to their densities in the state of vapour or gas.

Atomic heat.

Of the compounds of simple gases several undergo condensation, others do not. Thus two vols. of hydrogen and one vol. of oxygen, when combined, form two volumes of water vapour; one vol. of nitrogen and three vols. of hydrogen form two vols. of ammonia gas; one vol. of carbon and four volumes of hydrogen form two volumes of marsh gas. From this it evident that the greater the number of atoms contained in a molecule, the greater must be the condensation of the elements. An idea may be formed of the possible amount of this condensation by the consideration that a molecule of water vapour containing three atoms fills two volumes, while the same two volumes would be filled by a molecule of hematocrystalline containing 1,895 atoms, could this substance be brought into the gaseous state.

Condensation

The development of all vegetable and animal matters is effected by progressive condensation. This may be proved to be correct by the synthetical method. Elements are brought in immediate contact, and

Synthetical method.

* Silicinm, carbon, and boron.

† To this phosphorus, so common in the animal economy, and arsenic, form exceptions, being both too dense for satisfying that law, and cadmium and mercury form the exception on the opposite side, being both too expanded.

influenced by the application of forces which have the power to produce chemical movement; such forces are electricity, heat, light, or their conversions, such as pressure and concussion. Electricity may break up molecules and form them, and the formation of one set of molecules implies the breaking up of others; but not one or other, but all available synthetical powers are required to build up even simple substances in the laboratory. First elements are combined, then the combinations are condensed, then they are brought in contact with others and combined and simultaneously condensed, then additions are made, and when the dynamicities of all atoms are saturated, substitutions are effected. These processes lead to the knowledge of functional types, which might metaphorically be termed "organs of the chemical idea," or of chemism. These types are the following :—

Functional types.

1. Hydrocarbon (example, marsh gas), $\overline{C}H_4$.
2. Alcohol (methylic alcohol), $\overline{C}H_4\overline{O}$.
3. Acid (formic acid), $\overline{C}H_2\overline{O}_2$.
4. Aldehyde (ordinary aldehyde), $\overline{C}_2H_4\overline{O}$.
5. Ether (methyl-formic ether), $\overline{C}H_2\overline{O}_2+\overline{C}H_4\overline{O}—H_2\overline{O}$.
6. Alcali (methylamine), $\overline{C}H_5N$.
7. Compound metallic radical (arseno-methyle), $\overline{C}H_5As$.
8. Amide (formic amide), $\overline{C}H_3N\overline{O}$.

Structural types.

But with those functional types must not be confounded the structural types, which result from successive condensation of the type molecule hydrogen, HH, H_2H_2, H_3H_3, H_4H_4, H_5H_5, H_6H_6, &c., and substitution of one or several atoms by an equal number of dynamic monads. Thus by substitution of H_2 in the second type by a didynamic atom (equal to two monads) of oxygen, $\overline{O}^{II}$ (the roman numeral indicates the dynamicity as in the third column of the list of elements above given), water $\overline{O}^{II}H_2$ is produced. When in the third type H_3H_3, one factor is replaced by a tridynamic atom of nitrogen N^{III}, ammonia $N^{III}H_3$ results. From the fourth type results marsh gas ${}^{IV}H_4$ in a similar manner. From the fifth by substitution of one factor by a pentadynamic atom of phosphorus P^{V}, and of the second factor by five atoms of chlorine, Cl_5, the type perchloride, results, and so forth to an extent as yet unexplored. These types hydride (oxyde or acid or) water, ammonia, hydrocarbon, and perchloride may also inversely be derived from the dynamicity of the elements above supposed to be substituted, each monad being satisfied by the attachment of an atom of hydrogen. The theory of types served as a basis of classification and an instrument of discovery in the hand of its excogitator, Gerhardt. For similar purposes it has constantly been used in the following researches.

From the ideas of element, atom, molecule, condensation, and substitution, all types, all series, all chemical compounds derive; all chemistry has the chemistry of hydrogen for its type and unit.

II.—Sketch of Chemical Physiology, and of its Points of Contact with Pathology.

Digestion.

The food of man, variously prepared by mechanical processes and chemical operations (cooking), is comminuted in the mouth by chewing. At the same time it is mixed with a variety of fluids, some of which have chemical powers and predispose the food to a change, while others

serve mechanical objects only. The mixture of these fluids is termed saliva; but however homogeneous may appear that mixture, the properties of its components are very various. For the secretion of every particular kind of glands, of which there are four, differs, and the secretion of one and the same gland or set of glands may vary according to the agencies which call them into action. Underneath the forepart of the tongue is secreted from one and the same duct the saliva of a gland which lies under the tongue (sublingual), and that of two other glands which lie farther back on both sides of the tongue underneath the lower jaw (submaxillary glands). To collect either of these secretions little tubes have to be carefully introduced into the respective ducts, which is a matter of some difficulty. For this reason the chemical composition of the secretions of the separate glands is very imperfectly known. Experiments upon animals have shown that these glands can give four different kinds of secretion, according to the nerves which are irritated for the purpose. One nerve, a branch of the facial, and a continuation of the chord of the tympanum, on irritation causes a clear, slightly ropy secretion from the submaxillary glands. This "chordal" saliva contains about 4 per cent. of solid matters, of which 1·5 are globuline, mucine, and coagulable albumen; 2·5 per cent. are mineral, mainly alkaline chlorides and lime-salts; of these latter the carbonate, dissolved in excess of carbonic acid, frequently decomposes in the mouth, and deposits crusts of lime carbonate upon the teeth, which are popularly called tartar. On irritation of the sympathetic nerve the submaxillary glands secrete an opaque very tough saliva. This contains from 15 to 28 per mille of solids, amongst which is mucine, and granules or roundish lumps of an albuminous matter, and much free alkali. The third kind of saliva is that which flows when the submaxillary ganglion is made the centre of a reflex action which works by way of the lingual nerve. This is the only secretory act without the intervention of cerebrospinal influence that is known at present. The fourth kind of saliva is the "paralytic," or thin watery fluid which is secreted under the influence of nervous paralysis, caused either by degeneration, or poisoning, or wounds which separate the secretory nerves. Its composition is not yet ascertained.

Saliva.

Chordal saliva.

Sympathetic saliva.

Ganglionic saliva.

Paralytic saliva.

The mixture of sublingual and submaxillary saliva in man (not in animals) contains rhodanate or sulphocyanate (also termed rhodanide or sulphocyanide) of potassium and sodium C N K S, and C N Na S, recognized by the red colour which iron-chloride imparts to saliva, or to the distillate obtained from it with acids. In another part I draw attention to a similar reaction of urine, which differs however from that of saliva in this, that the body producing it is not volatile. These phenomena admit at present of no particular theory.

Rhodanates in saliva.

The saliva which is secreted by the parotid glands can easily be collected by the introduction of canulæ into the ducts. It is an alkaline, hardly viscous fluid, which contains a little albumen, some globuline, a particular ferment termed ptyaline, but no mucine. It contains much rhodanate, and is the most suitable material for preparing the distillate of rhodanic acid. It contains, water 995·3; solids 4·7; of these are organic 1·4; mineral 3·3; of the latter there is lime carbonate 1·2. The parotid saliva transforms starch into sugar by means of the ferment termed ptyaline. This is the only agent in saliva which has that power. It can be isolated by adding phosphoric acid and subsequently lime to saliva. Ptyaline adheres to the phosphate, is washed out by water, and precipitated by alcohol. It contains nitrogen but is not albuminous, refusing to yield the xanthoproteic acid reaction with nitric acid. The diastase of malt has a similar action used in

Parotid saliva.

Ptyaline.

Glycogeny.

trade fermentations. An interesting and important application has lately been made of diastase by Baron Liebig, for the production of a food for infants, and it is probable that the alkaline mixture supplies efficiently the want of alkali and ptyaline in the digestive juices of children who are being brought up without mother's milk, or with such as is not in a healthy state. Diastase acts best at 66°, while ptyaline is destroyed at 60°. An agent similar to ptyaline is emulsine, or synaptase of almonds, which has been recommended as a dietetic remedy in diabetes. But it does not seem to affect starch in any way, although decomposing amygdaline and salicine.

Diastase Liebig's food.

Emulsine or synaptase.

Amygdaline. Water. Oil of bitter almonds. Prussic acid. Sugar.

$$\overbrace{C_{20}H_{27}NO_{11}}^{\text{Amygdaline.}} + \overbrace{2H_2O}^{\text{Water.}} = \overbrace{C_7H_6O}^{\text{Oil of bitter almonds.}} + \overbrace{CHN}^{\text{Prussic acid.}} + \overbrace{C_6H_{12}O_6}^{\text{Sugar.}}$$

Salicine. Water. Saligenine. Sugar.

$$\overbrace{C_{13}H_{18}O_7}^{\text{Salicine.}} + \overbrace{H_2O}^{\text{Water.}} = \overbrace{C_7H_8O_2}^{\text{Saligenine.}} + \overbrace{C_6H_{12}O_6}^{\text{Sugar.}}$$

In these transformations sugar is a collateral product, while in that of starch by ptyaline or diastase it is the only product.

Starch.

Starch consists of two bodies, which in the little granules are disposed in alternating layers. The first is granulose, and has the property of being coloured blue at once by free iodine. The second is cellulose, not coloured blue by iodine at once, but only after sulphuric acid or zinc-chloride has been allowed to act upon it. When unboiled starch is mixed and digested with saliva for days, the granulose is dissolved out of the corpuscles and transformed into dextrine and sugar, and the cellulose only is left. At higher temperatures this also is changed. Boiled starch is more easily transformed, as the granules are burst and admit the altering juices between their layers with facility. The first symptom of the addition of saliva to boiled and cooled (to 40° C) starch or pap is increased fluidity, indicating the formation of soluble starch and dextrine. At a later period only sugar is formed, according to the following formulæ :—

Starch (synonym=amylon.) . . . . $C_6H_{10}O_5$

Soluble starch . . . } The same formula as starch.
Dextrine . . . . }

Dextrine. Water. Sugar.

$$\overbrace{C_6H_{10}O_5}^{\text{Dextrine.}} + \overbrace{H_2O}^{\text{Water.}} = \overbrace{C_6H_{12}O_6}^{\text{Sugar.}}$$

Amyloid degeneration.

Amongst the products of degeneration of the spinal marrow in locomotor ataxia, there are bodies resembling starch corpuscles, but consisting entirely of cellulose.

I had an opportunity afforded me of examining such a case, in which the sense which in physiology we now term the sense of pressure was almost entirely lost, while the sense of pain and the sense of heat and cold persisted. On examining microscopically, and by means of sulphuric acid and iodine, thin sections of the spinal marrow, I found in various parts of it agglomerations of blue bodies imitating in a remarkable manner wheat-starch coloured blue by iodine. The term *amyloid* is perfectly correct as applied to this particular degeneration. The reaction of these bodies, however like to that of amylum, is not that of amylum itself, for amylum is coloured blue by iodine alone, while these bodies require the concurrence of sulphuric acid and iodine.

Mixed saliva.

The secretion of the salivary glands mixed with the mucus of the membranes of the cavity of the mouth, secreted by little follicles,

constitutes mixed saliva. This can be collected in quantity by irritating the fauces with a feather, and producing vomituritions. It does not reduce alkaline copper solution, but retains a little copper oxyde in solution when copper salt and alkali only are added. It transforms starch into sugar, so that chewed pap after some standing, with copper sulphate and caustic potash, at 70° C, yields red copper suboxyde. It does not change cane-sugar into invert sugar, and thus differs from yeast. The quantity of mixed saliva secreted by a man in 24 hours varies between 300 and 1,500 grammes; it may be greatly increased by excitants, and irritating medicines and poisons.

Saliva in diseases.

Little is known of saliva in diseases, but the investigations of the future promise results. In diseases, such as salivation under the influence of mercury, rhodanates disappear. The saliva then contains mercury.

Anomalous ingredients.

Many medicinal salts pass easily into the saliva from the blood, such as iodide, chlorate of potassium, and when used long in quantity produce salivation. In diabetes the saliva contains lactates, but no sugar. In the paralytic saliva of hysteric persons leucine has been found. Acid saliva seems to contain lactic acid, and is of course anomalous. The presence of urea has been alleged, but not proved with certainty. In hydrophobia the saliva is the bearer of the contact-poison by which the disease is propagated to other individuals.

Digestion of starch.

While the saliva influences starch as indicated, and does not lose its action by the admixture of acid of the concentration of the gastric juice, it certainly does, under ordinary circumstances, not transform the whole of the starch into sugar. The gastric juice does not influence starch, the pancreatic juice to a trifling degree in the same sense as saliva. Deducting all sugar and lactic acid to be met with, it is necessary to assume that other products are formed, which yet elude analysis. Do any of these products find their way into the liver, and are these transformed into glycogen?

Glycogen of the liver.

Glycogen is a kind of dextrine, which was discovered in the liver by Bernard and Hensen. It occurs in three forms, of which one, of the formula $C_6 H_{10} O_5$, is powdery, two others $C_6 H_{12} O_6$ and $C_6 H_{14} O_7$ are gummy. It polarises to the right four times more intensely than dextrose sugar. With a solution of iodine in iodide it gives a dark red colour. It dissolves copper oxyde without reducing it. By sulphuric and hydrochloric acids, saliva, pancreas juice, serum of blood, and cold prepared extract of liver, it is transformed into dextrine and ultimately into sugar. Many physiologists have endeavoured to explain the source and destination of this matter, but as yet without any very complete success. Regarding its origin, it has been found that it could not be formed from sugar, as the portal blood did not contain any. It was not formed from fats. Animal food enabled animals to form it, whence the conclusion was drawn that glycogen originated in albumen. Seeing that the liver decomposes albumen, as proved by the constitution of the bile, this idea has much in its favour, but the experiments upon which it is based admit of different interpretation. Muscle frequently contains dextrine, always inosite (a particular kind of sugar), and lactic acid. All these might enable the liver of the animal which eats the flesh to form glycogen. At present it is at least uncertain from which material the liver forms glycogen; possibly it is formed out of starchy and albuminous matters at the same time, at least most of it is formed (up to 12 per cent. of the weight of the liver in fowls) when these two kinds of food are digested together in large quantity.

Destiny of glycogen.

As the dead liver was found to transform glycogen quickly into sugar, and as some sugar could be found in hepatic blood, it was concluded that glycogen is transformed into sugar, and passes into the blood, to be

there oxydised or changed as required. This view, upon which was based an entire theory, called that of the glycogenetic function of the liver, was received for some years by physiologists in general, until one of its greatest admirers, Pavy, believed that he had discovered it to be erroneous. According to him no sugar is made in the liver in the living healthy body. I showed that his experiments admitted of such variation as to prove either his or Bernard's doctrine. At present the bulk of evidence goes to show, that as a portion only of the starch in the intestines is transformed into sugar and passes into the chyle, so a portion only of the glycogen of the liver is transformed into sugar and passes into the blood. Quantitative experiments on a large scale, combined with the chemolytic method of research, will alone be able finally to decide the matters under discussion.

Mal-assimilation of starch.
Diabetes.

When sugar in considerable quantity exists in the blood, the body cannot deal with it, and excretes the sugar unchanged. Such a condition constitutes the disease termed diabetes, which appears to be a much more complicated disease than its main symptom taken alone would seem to indicate. The oxydation of sugar only is diminished or not accomplished, that of the albuminous substance and fats is rather increased, sometimes enormously so; therefore the carrying power of the blood corpuscles for oxygen cannot be diminished, as has been supposed lately, at least not in all cases of diabetes. There must be a perversion of chemical agency, as proved by the appearance of lactic acid in the saliva and of acetone in the stomach and the urine. On the whole there is at present neither a plausible theory nor a rational treatment of diabetes, as evidenced by the fact that noted physicians now maintain that diabetic patients eating promiscuously everything are better off than patients who abstain from starch and confine themselves to the anamylic diet so elaborately prescribed by Bouchardat. The sugar may be made in the liver or in the muscles, it may be the effect of a change of nervous influence (as suggested by the artificial diabetes of animals after wounds of the fourth ventricle of the brain), or of a failure in the supply of a ferment capable of transferring oxygen to it. The sugar when once in the diabetic blood appears not to be increased or decreased by standing of the drawn blood out of the body, the blood consequently contains perhaps no glycogen. This was ascertained by a special experiment, suggested by the medical officer, made upon the blood of a diabetic patient at St. Thomas' Hospital.

Digestion of the food in the stomach.
Gastric juice.
Pepsine.

The comminuted food mixed with saliva arrives in the stomach and excites this organ to a mechanical and chemical action, termed digestion. The many little rennet glands situated in the walls of the stomach secrete a liquid termed the gastric juice, which in man contains 994·6 pro mille of water and 5·39 of solid and permanently fluid ingredients other than water. Of these 3·0 are pepsine, 0·2 hydrochloric acid, with which perhaps a small quantity of lactic acid is mixed, and chlorides of the alkalies, with some phosphates of earths. Singular is the presence of some calcium-chloride in the juice. The juice has mainly been examined as obtained from persons who by accident had fistulous openings in their stomachs, and upon dogs upon whom such fistulas had been formed by operative interference. It led to the formation of artificial juice, which requires, however, the addition of natural pepsine, and is therefore only in part artificial. It serves, however, for the purpose of studying stomach digestion upon many kinds of food, and of supplying a kind of remedy in diseased conditions in which the natural juice is supposed to be deficient.

Gastric fistula.

Power of gastric juice.

This gastric juice possesses the power of dissolving or reducing to a liquid state albuminous substances, which are either by preparation,

such as boiling, or by nature, insoluble in water. Albumen, caseine, fibrine, syntonine, the albuminous substances of vegetables, gluten, and the collagene tissues or gristle, are under the influence of gastric juice, or of a mixture of pepsine and hydrochloric acid, dissolved to thickish somewhat turbid matters, to which the name of peptones is given. Pepsine may be isolated by mechanical precipitation in the same manner as ptyaline by adhesion to phosphate of lime. It is not itself destroyed during digestion, but is capable of transforming great quantities of solids into fluid by that mysterious influence termed contact action. When the juice is saturated with peptones it ceases to act, but an addition of dilute acid fluid enables digestion of newly introduced albuminous matters to be effected. The secretion of the hydrochloric (and lactic ?) acid from the stomach glands is a chemolytic process by which chlorides of alkalies are split up into acid and base. Of this action I shall show the completion of the circle in the biliary function immediately to be described. The origin of the pepsine is the blood, but which ingredient of this fluid yields this curious substance, which is so different from albumen, cannot be told. In the stomach digestion saliva by its ptyaline forms some sugar, the gastric juice fluidifies the albuminous matters, the fats are made fluid and liberated from their tissue connections, vegetable structures are variously disintegrated, and the whole is mixed with water and a small amount of air carried down in the process of swallowing. Other decompositions, as yet imperfectly understood, also take place, as evidenced by the strong odour of the digested matters, and at last the homogeneous mixture of matters, termed chyme, passes through the pylorus into the duodenum.

Peptones.

The ingredients of chyme are starch, sugar, fat, and peptones, or if only animal food had been eaten, fat and peptones alone. There are also undigested pieces of flesh, albumen, caseine, constantly present. It is at present impossible to say what these albuminous matters are. Some physiologists say there is only one substance, others that there are five and more, the statements as well as the experiments upon which they are based being quite irreconcileable with each other. None of these researches have as yet been carried out by means of the quantitative analytical chemical method, excepting the comparison of the composition of the peptones with the original matters. It was found that it was almost unchanged. The peptone solutions are not coagulated by boiling, but precipitated by absolute alcohol. They give Millon's reaction with nitrate and nitrite of mercury. They diffuse easily through parchment paper (dialyse) into water, exhibiting a property towards membranes of the utmost importance for absorption, which albumen possesses only in the very slightest degree. Optically they are characterised by turning the plane of polarisation towards the left.

Chyme.

Peptones.

The coagulation of the milk in the stomach, or by rennett out of it, is supposed by some to be due not to pepsine, but to another ferment which transforms sugar of milk or lactose into lactic acid, and precipitates the soda-albumen or caseine. This matter is problematical.

The quantity of gastric juice secreted daily in the human stomach has been estimated at 10 per cent. of the body-weight, or 16 lbs., other direct observations however lead to 30 lbs.

During digestion some gases, consisting of carbonic acid, hydrogen, and nitrogen, are not rarely formed from the digesting food. This may become a distressing symptom in disease.

Gases.

Duodenal digestion is a continuation of stomach digestion under greatly complicated circumstances. For the chyme receives additions of bile and pancreatic juice. The physiology of these liquids has been studied upon fistulous openings occurring accidentally in man, or pro-

Duodenal digestion.

duced by art in animals. The secretory acts and influences are no doubt well known, particularly their variations under several conditions. But the employment of the secreted matters is by no means so elucidated as to be capable of satisfactory theoretical representation. The pancreatic juice has probably three functions, of which one is the completion of the solution of the pieces of meat and albumen, which issue from the stomach with the chyme; another is the decomposition of fat into glycerine and fatty acid; and a third the emulging of neutral fat and transforming it into a subdivided condition, in which it may pass through the pores of the mucous membrane into the chyle-ducts. It also transforms a small quantity of starch into sugar. All the properties are only possessed by juice which is abstracted from the pancreatic duct of an animal during full digestion, or from a reddened pancreas. This juice is tough or viscid, and contains 10 to 11 per cent. of solids, while the juice which is obtained from a permanent fistula has only five per cent. of solids, and lacks the power of digesting albuminous fragments. It is probable that this deficiency is caused by a degeneration of the gland consequent upon the operative interference. The juice contains an albuminous matter at present undefined, possibly some mucine, mostly leucine, which is present in the parenchyma of the gland in larger quantities, and is more or less alkaline.

Pancreatic juice. Three functions.

Biliary functions.

The liver has an obvious function, and that is to secrete bile. It seems almost superfluous to make such a statement, but the views of physiologists regarding this organ have so often been perverted that it is necessary to recur to elementary principles. The error regarding the function of the liver which has crept into physiology has mainly been caused by the discovery in it of a substance which has the capability of being transformed into sugar, namely the above-described glycogen, also called hepatine, or liver-dextrine; and in consequence of that in itself remarkable and interesting discovery it has generally been believed that the main function of the liver was that of forming sugar. We know now that such is not the case.* The main function of the liver is one of considerable intricacy, and essentially connected with the great features of the process of digestion.

Connexion of stomach digestion with bile function.

Digestion in the stomach is produced by a process in which of chemical ingredients hydrochloric acid takes a main part. In the dog this hydrochloric acid is so strong that the hardest bones are absolutely dissolved. In man such a solution of bones cannot easily take place, but they are certainly corroded when they are introduced into the stomach. The acid which dissolves them in the dog is hydrochloric acid only; in man the acid is probably a mixture of hydrochloric and lactic acid. But although we find in the economy chlorides everywhere, and lactates constantly in the chyle, yet we do not meet with these acids in the free state. We are therefore obliged to assume that in the walls of the stomach a chemical process is constantly taking place by which hydrochloric and lactic acids are being formed. This process is very simple, consisting in the separation of the chlorine from the sodium chloride (or common salt), and the combination with it of a certain quantity of hydrogen. This hydrogen is derived from the water. What then takes place in the glands of the stomach may be stated to be a

* See the articles of Pavy on this subject, Guy's Hosp. Rep. 1858, iv. p. 291; Phil. Transact. 1860, p. 595, and my critical experiments in Brit. Med. Journal, Vol. I., 1860. In these latter the analytical method now generally followed was first used and published; it was afterwards adopted by Pavy, Bernard, Kühne, and others. For confirmation of the variable results see Meissner, Jahresbericht für, 1862, p. 310, et seq. Ritter, Amylum und Zucker in der Leber. Zeitschr. f. rat. Med. 24, 65. Eulenburg, Journ. für Pract. Chem. 103, 108, 1868.

splitting-up of water and sodium chloride, and cross combination of the elements to hydrochloric acid on the one side and sodium hydroxyde on the other.

$$\underbrace{H\Theta_2}_{\text{Water.}} + \underbrace{NaCl}_{\text{Common Salt.}} = \underbrace{HCl}_{\text{Hydrochloric acid.}} + \underbrace{NaH\Theta}_{\text{Sod. hydroxyde.}}$$

The lactic acid is produced from lactates in a similar manner, and in the formula of its formation the place of chlorine in the foregoing formula would be occupied by the formula $C_3H_2\Theta_2$ of lactic acid. This is simple and certain. But we find in the body no caustic soda, or sodium hydroxyde, and we are therefore driven to inquire what becomes of this caustic soda so produced.

Why the stomach does not digest itself.

Before it is carried away from the gastric glands by the blood, a part of this sodium hydroxyde has an important function to perform, namely, to protect the stomach against the corrosive action of its own secretion.* It keeps the blood and tissues more alkaline, and prevents the acids and pepsine, which have become more energetic after secretion and mixture with the peptones, from corroding the texture of the stomach. (Such corrosion immediately takes place in cases where the supply of blood to a part of the stomach is interrupted, or where food remains in the stomach undigested after the secretory energy has passed away; gastric ulcer, hematemesis, chronic dyspepsia, or painful digestion with follicular erosion, and other pathological conditions, are produced in this way.) The sodium hydroxyde is soon transformed into carbonate in the blood, and passes through the gastric veins into the portal, and thus into the liver. When we analyse bile and add to it a quantity of acid, we precipitate certain matters, namely, the biliary acids formed by the liver, and the cholophæine; and if we evaporate the liquid we get a large quantity of sodium combined with the acid which we have added. Supposing now that the acid added was hydrochloric, we find at the conclusion of our experiment that sodium has been combining with chlorine and that we have sodium chloride, and that the hydrogen of the acid has again combined with oxygen (hydroxyl) and formed water.

Bile.

$$NaH\Theta + HCl = NaCl + H_2\Theta$$

That is to say, by boiling bile with hydrochloric acid we reproduce the chloride of sodium which before has been decomposed in the walls of the stomach. In our food we take no salt of sodium combined with biliary acid, or any acid that can be transformed into it. We take many substances containing sulphur and nitrogen which can furnish the biliary or special organic part of the bile, but not the soda salts contained in it. Their production is just the function of the liver. The liver splits up or chemolyses albuminous substances or albumen into products of which a part is at present unknown, another part, however, well known under the name of biliary acids and coloured ingredients. They are taurocholic acid, glycocholic acid, cholophæine, bilifuscine, biliprasine, choline, and cholesterine.

Taurocholic acid ($C_{26}H_{45}N\Theta_7S$) contains all the sulphur of the bile. By this ingredient it manifests itself as a derivate of albumen, which also contains sulphur. Glycocholic acid ($C_{26}H_{43}N\Theta_6$) is nitro-

* This function was clearly developed and stated by me in Brit. and Foreign Med. Chir. Review, Oct. 1861, p. 429. At a later period it was made the theme of some interesting experimental inquiries by Pavy (Philos. Transact. 1863) who was, however, not aware of my publication on the subject.

genous only, and free from sulphur. Both acids yield by chemolysis an acid free from nitrogen and sulphur, cholic acid ($C_{24}H_{40}O_5$). But the sulphuretted acid yields as the second product a body containing all the sulphur and nitrogen of the original acid, taurine = $C_2H_7NO_3S$ = dehydrated isæthionate of ammonia, and producible from such; while the other compound acid yields as the second product of its cleavage glykocoll or amido-acetic acid, $C_2H_5NO_2$, which is producible artificially by various processes. The rational constitution of the smaller nuclei is thus shown to be well known; but the same could not be said of cholic acid. Glykocoll appears in an excretion as hippuric acid (in which it is coupled with benzoic) but it is at present uncertain whether this excreted glykocoll has previously taken any share in the composition of bile or not. Taurine, however, is consumed in the body, and its sulphur appears in the excretion as sulphuric acid.

As the chemical nature of cholophæine, bilifuscine, and biliprasine has only lately been evolved by my researches, I refer to the extracts of the technical papers, given in the subsequent pages, for particulars. Their chemical composition is now better known than their physiological meaning, which remain for future inquiry. Cholesterine ($C_{26}H_{44}O$) occurring in the brain and blood is no doubt excreted by means of the bile. It is a polydynamic alcohol, capable of forming ethers analogous to fats. Coloured matters and cholesterine are the main residues of certain diseased processes which terminate in the production of calculi. In a degeneration of the liver, called bacony, considerable quantities of cholesterine remain stagnant in the parenchyma of that organ. The choline of the bile is an organic base of the composition $C_5H_{13}NO$. It is perhaps identical with neurine, a base obtainable from cerebric acid.

Pettenkofer's test.

The biliary acids yield a particular test, called, after its discoverer, Pettenkofer's reaction. When mixed with sugar and sulphuric acid they produce a splendid purple colour. It has been found that other acids, such as lithofellic, also yield this test; and I found, further, that cerebric acid yielded it with rare intensity. I therefore applied the spectroscope, and was glad to discover some means for the distinction of the various acids in the coloured test solution. The biliary acids show two bands, cerebric acid and vitelline only one (see Plate III.). These spectra are, however, difficult to observe, and require sunlight or oxyhydrogen light for their complete development.

Quantity of bile in man.

The quantity of bile secreted in the human body in a day has been estimated at 1,200 grammes, or the bulk which would fill a wine bottle and a half. Conclusions from quantities observed in animals can only be used with caution, as some animals, e.g., the guinea-pig, produce enormous quantities of bile relatively to their body weight, while dogs and sheep produce relatively small quantities. The production is more likely to stand in proportion to the size and weight of the liver (hitherto neglected as a physiological factor) than to the weight of the body, to which hitherto quantities were almost exclusively referred.

The bile in the intestine.

The function of the bile in evidently like its chemical constitution, very complicated. Stored during intervals between digestion, it is mainly secreted as well as expelled from the bladder during digestion, and a particular quantity of it during a peculiar episode at the end of the emptying of the stomach. On being mixed with the acid of the chyme, the biliary acids are set free, but not precipitated, as the soluble taurocholic acid holds the glycocholic in solution. But a precipitate of peptones is nevertheless produced in the mixture of chyme and bile.

This, mixed with the bile-acids and the biliary colouring matter, passes along the intestine as a resinous adhesive substance, to be altered and made absorbable by the many influences of intestinal reaction. It is soluble in alkali, and as much of the intestinal secretion besides gastric juice is alkaline, the transformation meets with no difficulty. The peptone then may pass into blood and chyle as albumen and fibrinogen and fibrinoplastic matter, but the bile is not so easily accounted for. The acids certainly split up, taurine and glycocoll returning into the circulation, but the cholic acid mainly disappears, without leaving any trace in the blood or chyle; neither contain a trace of biliary matter. In the fæces only occurs a small proportion of the cholic acid, amounting in man to from two to three grammes, being perhaps one-eighth or one-twelfth of the entire amount secreted. The cholophæine has been also changed and become insoluble in chloroform. We must therefore assume that the cholic acid is already split up or chemolysed in the intestine, and reaches the circulation in the more simple form of products of its decomposition. The bile influences fats and fatty acids in the manner of a soap. It communicates to the small absorbing tubes an attraction for fat, so that capillarity raises the fat to a higher point than the same vessel would do without bile. Bile then represents the accomplishment of a purpose which we term chemolysis of albumen. But the further uses of bile are numerous and important; the excretion of cholesterine, intimately related to the chemistry of the nerves, and possibly a product of their action; the excretion of choline, of which the objects are continuous; the excretion of cholophæine, of which the objects are at least obscure. Bile precipitates pepsine, and when it regurgitates into the stomach arrests digestion completely. It therefore puts an end to pepsine digestion in the duodenum, and favours the alkaline pancreas-digestion. In disease the bile may be retained and cause jaundice, and slowness of the pulse; or it may be decomposed in a peculiar manner and produce concretions; in man these consist of cholesterine and modified bile-acid, and bilifuscine, with cholophæine and earths; in oxen the cholophæinate of lime predominates, and modified bile-acid with lime-soaps are in lesser quantity. In pigs these calculi contain a peculiar lime salt, which assumes a voluminous crystalline form, when the powder is digested cold with alcohol. The pancreas has in diseases been observed to be degenerated and cancerous; and as in these cases lumps of fat are stated to have been observed in the fæces, this appearance of fat has been ascribed to the failure in the supply of pancreas-juice. In lientery the pancreas as well as the stomach and pylorus is probably at fault.

Fate of peptones.

Changes of bile.

Bile in diseases.

Pancreatic juice in diseases.

The digestion in the small intestine is very imperfectly known, and requires particular and great researches in the future. In this part of the body is the constant and principal seat of diseased processes of the greatest importance, *e.g.*, typhus and typhoid fever, cholera and others, not the least important amongst them the æstival and autumnal diarrhœa so fatal to many persons in every year without special epidemic influences.

Digestion in the small intestine.

Glycerine is a tridynamic alcohol, constructed according to the type of water thrice condensed. In this type there are six atoms of hydrogen replaceable; when three of these are replaced by the radical glyceryl (which is a tridynamic radical) glycerine is formed. Glycerine, therefore, has three atoms of typical hydrogen, which can be replaced by three atoms of a monodynamic body or one atom of tridynamic body. It is not necessary to substitute all the hydrogen at once, when we work synthetically, but in animal bodies all the hydrogen is always replaced

Fats of the human and animal body.

by fatty acids. A fat is thus shown to be a body of the type of three atoms of water condensed to one, thus—

$$\left.\begin{matrix} H_3 \\ H_3 \end{matrix}\right\} O_3$$

in which three atoms of hydrogen are replaced by one atom of glyceryl^{III}, and three others by three atoms of fatty acid radical^{I}. Tributyrine, a fat occurring in butter, has this formula :—

$$\left.\begin{matrix} \text{3 Monodynamic atoms of Butyryl} = \begin{cases} (C_4\,H_7\,O)^I \\ (C_4\,H_7\,O)^I \\ (C_4\,H_7\,O)^I \end{cases} \\ \text{1 Tridynamic atom of Glyceryl} \quad = (C_3\,H_5)^{III} \end{matrix}\right\} O_3$$

held together by three didynamic atoms of typical oxygen.

The roman numeral to the right of the radical butyryl signifies that it is a monodynamic radical, and can replace only one atom of hydrogen ; but the roman numeral to the right of glyceryl shows it to be a tridynamic radical, which by its one atom replaces three atoms of hydrogen.

The other fats occurring in the human body and in animal food are tripalmitine—

$$\left.\begin{matrix} 3(C_{16}\,H_{31}\,O_2) \\ (C_3\,H_5)^{III} \end{matrix}\right\} O_3$$

which is equal to the large formula of

$$C_{51}\,H_{98}\,O_6,$$

tristearine, a fat abounding in mutton and beef, of the formula

$$C_{57}\,H_{110}\,O_6$$

and trioleine, a more fluid flat, which abounds in the oils extracted from lower animals and vegetable seeds.

Digestion of fats.

When these fats have passed through the stomach, and after solution of all tissue by which they are held together in the parts of animals, arrive as fluid oils in the intestine, they are acted upon by the pancreatic juice and the bile. The former affects them in two ways. A small portion it decomposes, so that glycerine and fatty acid are formed, another portion it emulges, or makes fit to become subdivided into the very minutest mechanical molecules, and in that state to pass through the small pores of the cylindric cells which cover the villi of the intestine. The fatty acids mostly combine with soda and pass as soaps into the venous blood, and with this to the liver; while the emulged neutral fats pass into the lymphducts, and by them into the venous blood, without passing through the liver. After incorporation with the blood the fat is burned up in the system, particularly the muscles.

Phosphatic emulsion of stearic and palmitic acids.

But there is yet a particular form in which fatty acid is found in the body, namely, emulged in phosphate of sodium solution. When palmitic or stearic acid is boiled with common sodium phosphate. it forms a milky fluid; the acid is so finely subdivided that the microscope can distinguish only the very finest molecules. When this process is applied to neutral fats, or to oleic acid, no effect is produced. The emulsion is a very loose combination, inasmuch as ether extracts the fatty acids. This particular form of fatty acid emulsion occurs in liphæmia, or fatty blood disease, in chylous urine, and in several effusions into internal cavities.* Its formation is a normal occurrence, the phosphate of sodium of the food (bread) yielding the mineral ingredients for the carrying on of the process with the digested fat in the intestinal

* Compare on this subject my researches published in "The Lancet," 1864, Vol. I., p. 434, Liporocele.

canal ; if the phosphate be wanting in the food, the bile, which always contains notable quantities, will supply it [and it is to this action of the phosphate in bile that any influence upon fatty acids which it possesses is due, the action upon neutral fats formerly ascribed to it being an erroneous conception]. The anomaly in the above-mentioned diseases is the persistence of the fatty emulsion in the arterial blood, whereby an obstruction of the circulation and consequent effusion (of blood, serum, fatty and fibrinous serum, as in apoplexy, dropsy, chylous urine, and other diseases) is produced.

Fatty degeneration.

Fat having been frequently found in degenerating tissues, deposited in visible manner, in parts where healthy structure shows no visible fat, microscopic anatomists admitted a particular fatty degeneration, in which fat in excess assumed the place of albuminous matters. The heart was supposed to be particularly subject to this disease, to which, however, all other tissues paid tribute. This doctrine, however, is at present in a very unsatisfactory state, and requires much elucidation by researches conducted upon mathematical principles. That fatty degeneration so called may be a very complicated chemical disorder, I showed many years ago by the demonstration of changes in the myochrome of the muscles of the heart, which produced a green granular pigment.†

Chyle.

Chyle is the fluid which the lymphatic vessels of the villi of the intestine absorb from the digested food and carry to the blood. It contains much fat, to which it owes a white milky appearance. It further contains the ingredients for the formation of fibrine, and curdles soon after it is withdrawn from circulation. Then there is potassium-albumen, and the ordinary albumen of serum. There are also lactates, sugar, and urea contained in chyle, besides a certain amount of alkaline salts. Chyle is the material by means of which the blood is constantly renewed. It contains mostly some white and red blood-corpuscles, which leads to the idea that they might perhaps be formed in certain lymphatic glands through which the chyle has to pass. Before entering the blood chyle is always mixed with a considerable quantity of lymph, which differs from chyle mainly by the absence of fat in emulsion. The lymph is transuded serum of the blood, which penetrates into the tissues and there performs its functions ; it is then reabsorbed and carried back to the circulation by the lymphatic vessels. There are many derangements of the lymph and chyle which occur simultaneously with diseased glands in scrophula, and in tuberculosis, and it is probable that improper nutrition has the main share in the production of these derangements in a great number of young children.

Chemical constitution of the red blood-corpuscles.

The peculiar shape of the blood corpuscles appears to be partly dependent upon their chemical constitution. This latter is the product of their own powers and their interchange with those of the surrounding serum. They have a certain specific gravity, which is maintained or varied (in diseases, in different classes of animals) by the quantity of certain chemical ingredients which are within them. Amongst these latter most notable by its red colour, and in the first place by its chemical constitution, is hematocrystalline or cruorine.‡ This substance contains carbon, hydro-

Hematocrystalline or cruorine.

† *See* Transact. of the Pathol. Society, 6, 134 ; and Quarterly Journal of Microscopical Soc. No. 14.

‡ When the blood crystals were first discovered and their various shapes and properties found out (Funke, Kunde), it was believed and stated (Lehmann) that they consisted of a colourless substance (hematoglobuline) to which a coloured matter (hematine) adhered like a dye. As long as the researches on this subject moved on the microscopic field only this idea was plausible ; for many crystals are actually so thin as to appear colourless under the microscope. But the chemical and spectroscopical researches of the last few years have established the error of this conception and substituted the doctrine of the text. Cruorine is a synonym which was first proposed by Denis, and has lately been again revived by Stokes.

gen, nitrogen, iron, sulphur, and oxygen, in the proportions indicated by the following formula : $C_{690}H_{967}N_{154}FeS_3O_{177}$. This leads to an atomic weight of 13,280, but if the atomic weight be determined by the quantity of iron, an atomic weight of about 13,000 is arrived at. Persons who have not studied this branch of chemistry, and who perhaps in their handbook, do not read of atomic weights rising above 500, may wonder at the high atomic weight here assigned to hematocrystalline. But this body can now be obtained pure in drachms and ounces, and the analyses of crystals by Lehmann, Schmidt, H. Seyler, and others, have always shown them to contain four-tenths per cent. of iron. The crystals are mostly of the rhombohedric system, and appear in tetrahedra, octahedra, with and without prisms, or in prisms only. Their watery properly diluted solution, when examined in the spectroscope, shows two remarkable bands of absorption, and obscuration of the blue and violet end of the spectrum, as represented in fig. 1 of Plate I. As the blood of all vertebrate animals, when viewed within the living blood vessels, shows the same bands, we can assume that hematocrystalline is present in it as such, and not formed by the process of preparing the crystals. Hematocrystalline can be deprived of its oxygen, and then its spectrum changes to that of reduced hematocrystalline (fig. 2, Plate I.) Shaking with oxygen restores the double-banded spectrum. The two bands therefore belong to arterial blood, the one band to venous blood (Stokes). Hematocrystalline contains as proximate constituents an albuminous body, which after separation remains amorphous and colourless, and hematine, which retains the colouring power, the spectral influence upon light, and the iron of the original substance, though all varied in kind, proportion, and quantity. Hematine has an atomic weight of about 620, and from 7·5 to 8 per cent. of iron. It yields many remarkable products of decomposition which will be treated of lower down. Its spectra in various solvents and in the reduced state, and the spectra of a number of new derivates, are represented in figures 3 to 10 of Plate I., and figs. 1 to 5 in Plate II. The optical and chemical phenomena of hematocrystalline and hematine are applicable to medico-legal research, as affording the most certain diagnosis of blood upon the smallest quantities of material. A diminution of hematocrystalline in the body constitutes the disease termed "chlorosis" or "anæmia." It is either a specific ailment, or a symptom and consequence of chronic disorders, or acute, particularly tropical fevers.

Shape of crystals.

Spectrum of oxydised and reduced hematocrystalline.

Hematocrystalline splits up into albuminous body and hematine.

Besides hematocrystalline the blood corpuscles contain a quantity of cerebric acid, with an atomic weight of certainly not less than 2,115. This has been variously called myeline (Virchow), protagon (Liebreich), and other names, but it is the same body as that which can be extracted from the brain. We further have in blood corpuscles a certain quantity of what is called stroma. This is merely a name for a substance which is supposed to give them a shape. The stroma remains when the other bodies are extracted. It is a kind of chemical skeleton, and can be isolated (by freezing, for example) and investigated (Rollet). It seems to be very different from the albuminous matters combined in hematocrystalline, for it is soluble in ether, alcohol, and chloroform, when these agents are dissolved in serum. But it contains a small quantity of fibrino-plastic substance (Alex. Schmidt), namely paraglobuline, sometimes also termed *globuline*. This remains insoluble when the blood corpuscles, previously separated from serum by solutions of salt, are deprived of hematocrystalline by water. The gelatinous paraglobuline, after shaking with water and ether, is soluble in solutions of salt, dilute alkalies, and water containing

Cerebric acid in blood corpuscles.

Stroma.

Stroma contains paraglobuline.

one per mille of hydrochloric acid. Brought in contact with fibrinogenous solutions it frequently produces fibrine.

Function of the blood-corpuscles.

The blood-corpuscles carry oxygen, which has great affinity for hematocrystalline, from the lungs to the most distant or hidden and internal parts of the body. They there yield it up to the tissues, principally the muscles or the oxydisable matters contained in their juices, and the tissues, thus oxydised, return the carbonic acid, water, urea, and other products into the blood. The muscles may either oxydise immediately or store the oxygen in large quantities by means of their red colouring matter, which is identical with hematocrystalline, particularly during sleep. Although the carbonic acid affects the colour and condition of the blood corpuscles, nevertheless the latter are not carriers of the carbonic acid. This gas is in the serum. It is there partly dissolved in the same manner as in soda or Seltzer water, but to a great extent it is combined with alkaline bases, particularly sodium. When the blood-corpuscles of the venous blood arrive in the lungs, they have undergone a change which consists in the partial oxydation of a small quantity of their hematocrystalline, and this is transformed into an acid which I will call hematic acid. This blood-acid contains nitrogen. It is not similar to any of the acids we know. It is not volatile but fixed; it is evolved from the blood corpuscles and passes into the serum at the very moment when the former arrive in the small breathing cells of the lungs. There the blood acid combines with the sodium and the carbonic acid is set free, and is left to take its course, with water-vapour, through the lung tissue into the respiratory passages.*

Carbonic acid is in the serum.

Hematic acid.

Blood change in cholera.

In my research on cholera I have shown that the serum of the blood, in consequence of the alvine flux changed in its constitution in that disease, refuses to perform the functions which it performed before. It exhausts water and other matters from the blood-corpuscles, and the latter thereupon cease to carry oxygen; oxydation does not take place any longer, hence the temperature falls, and the algid condition of cholera is produced. In yellow fever, and in a disease which occurs in England, intermittent hematuria, the hematocrystalline of a portion of the blood corpuscles leaves them, and in the one disease decomposes and colours the skin yellow, in the other appears in the urine with a red or reddish-brown colour. A similar decomposition takes place in some cases of pyæmia, and in poisoning by arseniuretted hydrogen, and by the bite of venomous serpents. Several poisons, such as sulphuretted hydrogen, carbonic oxyde, hydrocyanic or prussic acid, kill or injure by decomposing the hematocrystalline, or combining with it and keeping the oxygen out. Of these I will treat below, when considering the application of the spectroscope to pathology and toxicology. Thus the study of many diseases requires an intimate knowledge of the constitution of the blood corpuscles. The value of this we have only just begun to appreciate, and the chemical and optical methods of investigation applied with rigorous accuracy will bring us not only the explanation of normal phenomena at present remaining obscure, but also useful practical information on the nature of diseases, processes of poisoning, and their treatment by prevention or cure.

* The excretion of carbonic acid from the lungs is an act of specific secretion, to which the presence of oxygen (and nitrogen) may be a supplementary advantage (as favouring diffusion), but is not essential. Hüter's observation of twin fœti, which were born living within the uninjured membranes and surrounded by the liquor amnii, and in that condition exhaled gas, are to me conclusive evidence of this, as also of my proposition that the act of first breathing is an act of secretion. This theory is fertile of explanations of many dark phenomena, such as the peculiar power of new-born children to sustain prolonged states of asphyxia.

Coagulation of the blood. Fibrinoplastic and fibrinogenous matter.

One of the most remarkable properties of the blood is its power of coagulating or setting shortly after it has left the body. Of this phenomenon many ingenious theories have been given, but none has yet satisfied the demands of exact chemical science. The latest and most plausible one is that of A. Schmidt, according to which the serum contains two substances, which have the power of combining with each other or forming fibrine, or the substance which produces the phenomenon of the curdling of the blood, as caseine produces that of the milk. One of these matters has been termed fibrinoplastic substance (paraglobuline) contained in serum and corpuscles, the other fibrinogen, contained also in serum and other fluids of the body. There is no doubt that substances answering to these descriptions can be isolated, and when brought together mostly form fibrine. But what is not yet proved is that they combine in atomic proportions. It is just possible that the paraglobuline only acts as a ferment like rennet, and transforms fluid fibrinogen into gelatinous, solid, or fibrous fibrine, by the power which in chemistry is termed contact action. But even should this theory be confirmed as at present shaped, it would fail to afford any answer to the obvious question after the inhibitory power which prevents these bodies from reacting upon each other in the circulating blood. The question of the cause of the coagulation being answered would make room to the question of the cause of the fluidity and non-combination of these bodies during life and circulation. This would no doubt be a progress, but not a solution. It is a fact that blood while in contact with the inner surface of healthy blood-vessels in living bodies, even when prevented from flowing by double ligatures, does not coagulate. Even coagulated blood, when placed into the cavity of the excised heart of a turtle becomes fluid again. From these and similar facts the living walls of blood-vessels were said to be the agencies which kept the blood fluid (Brücke). But such a statement is only a circumscription not an explanation of the fact, which therefore requires further study and investigation.

Circumstances under which blood keeps fluid.

Fibrine contains albumen, physiolysis.

It must always be borne in mind that by the method of physiolysis, or putrefaction conducted upon certain principles and with certain precautions, fibrine yields albumen, and that consequently the atomic constitution of fibrine must be more complicated, and its atomic weight higher than that of albumen.

Chemical constitution of the serum.

Paraglobuline.

Sodium and potassium albumen.

The yellowish liquid which remains when the fibrine has been allowed to set in the blood, and to enclose and retain in its contracting meshes the blood corpuscles, is termed the serum. It contains yet a quantity of paraglobuline, of which only a small portion has been used up towards the formation of fibrine. It further contains sodium albumen (or caseine of serum, Panum), and a very small quantity of potassium albumen. The paraglobuline is precipitated by carbonic acid from serum diluted with 10 water, the albuminates dissolved in combination with the alkaline metals are set free by little acetic acid. But the ingredient of serum which is present in the largest quantity (7·9 to 9·8 per cent.) is the albumen particular to the serum, or blood albumen, as distinguished from the albumen or white of egg. This is completely precipitated by boiling in the presence of a little acetic acid. If no acetic acid is present, sodium albumen, formed during the process of coagulation, remains in solution.

Blood or serum albumen

Neutral fats and soaps.

Free fatty acids in emulsion.

The serum contains neutral fats and soaps in solution or suspension, in the latter case being rendered milky or turbid thereby. In cases of disease which I have made known the serum also contains free fatty acids. These acids are emulged with the phosphate of sodium of the serum, and after extraction by ether are again easily emulged by boiling with a solution of common sodium phosphate in water. A similar emulsion I have shown to occur in so-called chylous urine, and in

certain effusions in the scrotum, termed variously milky hydrocele or lactocele. The serum further contains cholesterine, creatinine, urea, and hippuric and lactic acid in small quantities. In gout, uric acid as urate of sodium and calcium is found in it; in diabetes, sugar. In jaundice, biliary colouring matter, or cholophæine; and in leukocythæmia, formic acid, xanthine, and other matters.

Mineral salts in serum.

Of inorganic salts the serum contains sodium chloride, sodium dicarbonate, and calcium phosphate, small quantities of magnesium phosphate, still smaller ones of potassium salts. The chemical operations of the serum (and blood on the whole) employ sodium salts mainly, while those of the muscles chose salts of potassium mainly. We have seen how the function of the liver employs the sodium as the principal mineral base for its peculiar acids. But an explanation of this strict separation has yet to be found. We are more confused than enlightened by the discovery of the apparent paradox that fish, living in a medium abounding with sodium salts, should form a bile the mineral base of which is potassium.

Gases in serum.

The serum contains nearly the whole of the carbonic acid contained in the blood, particularly when it becomes venous. This is present in two forms, the one dissolved and removable by the vacuum, the other combined with sodium as carbonate and dicarbonate, and dislodged only by acids and boiling. It is also possible that the sodium phosphate attracts a portion of carbonic acid and holds it in peculiar loose combination.

The particulars of the changes which the ingredients of serum may undergo in the febrile and zymotic diseases will be discussed under the respective headings.

The physiology of the gases of the blood, of the oxygen, nitrogen, and carbonic acid contained in its modifications of arterial and venous character, has only lately been perfected by instruments and methods satisfying all demands. These methods will in future have to be applied to pathological research on a more extended scale.

Quantity of blood in a man.

The *total* quantity of blood contained and circulating in a living man has for many years been greatly over-estimated, owing to fallacious conclusions derived from the practice of blood-letting. The best methods available about 10 years ago reduced the quantity to 7·7 per cent. of the weight of the body (Bischoff). But this has to be again reduced, as in these processes the myochrome was not deducted from the hematocrystalline, by the quantity of which the blood was estimated. Seven per cent. of the weight of the body will probably be a more correct estimate of the quantity of the blood than any other hitherto made.

Striated muscles.

The striated muscles consist of particular contractile matter, arranged in layers within a fine membranous bag (sarcolemma) and connective tissue. The contractile matter is arranged in disks consisting of syntonine, which are laid close together, separated and surrounded, however, by a particular plasma. This can be isolated from muscles treated at the freezing point, taken out of the animal just killed, or from cold-blooded animals, such as frogs. The plasma is alkaline, and coagulates on standing like blood; by beating the coagulation is favoured. The coagulum is termed myosine; it is flaky, never fibrous, and more transparent than fibrine. Plasma dropped into warm water coagulates instantaneously, and deposits pure myosine. Like fibrine, myosine decomposes peroxyde of hydrogen. By solution in dilute acids it is transformed into syntonine. This is the name of the solid part of the flesh tissues, the particular fibrine of flesh of Liebig, which, insoluble in water, can be extracted from the insoluble part of meat by dilute

Muscle-plasma.

Myosine.

Syntonine.

Muscle-serum.

First albuminous matter.

Potassium-albumen.

Serum-albumen.

Myochrome.

acids in large quantities. The muscle-plasma, after coagulation of the myosine, leaves the muscle-serum. This becomes quickly acid, like all meat on keeping, and on neutralization deposits an albuminous substance. The fluid on acidification precipitates albumen which was in combination with potassium. This precipitation occurs in the meat naturally by formation of paralactic acid, which at first shares the potassium of the phosphate, and transforms it into acid phosphate. To this belongs the acid reaction of kept meat. Only when excess of paralactic acid in its free state is present does the albumen separate from the potassium-albuminate. Besides these two modifications the muscle-serum contains the ordinary serum albumen of blood. There is also contained in the serum of the red-coloured muscles a coloured albuminous matter, myochrome, identical with hematocrystalline. In white muscles this matter seems to be absent. When flesh is extracted with water the albuminous matters contained in this solution are precipitated by boiling (albumen curdles at 65° C, hematocrystalline only at about 90° C), a faintly yellow broth is obtained, which when made of mutton retains that name, but when made of beef is popularly termed beef-tea. This mysterious fluid, which is of great dietetic value to the healthy and the sick, contains a great number of remarkable ingredients—creatine, $C_4H_9N_3O_2$; creatinine, $C_4H_7N_3O$, the former a neutral body, the latter a powerful organic base, which also appears in the urinary excreton; uric acid, $C_5H_4N_4O_3$; xanthine, $C_5H_4N_4O_2$; hypoxanthine or sarkine, $C_5H_4N_4O$; guanine, $C_5H_5N_5O$; all of which appear in the urine of man or of the lower animals; taurine, the body obtainable from taurocholic bile-acid, and which may therefore be perhaps formed in the muscles, and carried to the liver, or be formed in the liver and carried to the muscles, or be formed in both in different ways; inosic acid $C_5H_6N_2O_5$, and acids of analogous composition; further bodies free from nitrogen, as paralactic acid $C_3H_6O_3$; formic, acetic, and butyric acids; glycogen, the same as that in the liver; dextrine; sugar or grape-sugar; and a particular kind of sugar also found in the green shells of French beans, namely, inosite $C_6H_{12}O_6 + H_2O$. The total of these bodies which are known amounts to two grammes from the extract of 1,000 grammes of flesh; but the total amount of extract obtained is 12 grammes of organic substances. Consequently five-sixths of the extracts of meat are at present quite unknown to us. The extract of the meat of animals, oxen and sheep, has now become an article of wholesale manufacture and of trade. It contains 18 per cent. of salts, of which nearly half the weight is potash. The economic advantages of this extract are the direct result of the purely scientific studies of Baron Liebig, and have made his name literally a household word. The residue of meat from which the extract has been pressed contains all matters insoluble in water, syntonine, myosine, sarcolemmata, with nuclei, and fat. Some of this fat is visible under the microscope in the fibre, but some is invisible and dissolved, though not as soap. The residue contains phosphate of potash in insoluble combination with an organic matter, but no chlorides.

Beef-tea.

Ingredients of beef-tea.

Extract of meat.

Residue of extracted meat.

The muscle is a machine for the transformation of chemical into mechanical force, and for the storing and exercise of that force. The exercise is partly constant and involuntary, partly intermittent and subject to the will. The loaded muscle is alkaline, full of disposable oxydisable matter, and of oxydant, namely oxygen. The nerves of motor influence effect chemical contact and immediate contraction of the various elements. The muscle becomes acid during work, and gives off large quantities of

carbonic acid. The disintegration of its albuminous matter seems hardly to be increased immediately, but that of the carbonaceous substances is evident. Muscular exercise does not increase the excreted urea quantity, but that of the carbonic acid exhaled perhaps to tenfold the amount excreted in rest during equal times. The muscle participates in all febrile diseases of the body, and is frequently the seat of idiopathic processes. In typhoid and typhus fever it becomes disorganized in a high degree, losing structure, and assuming a yellow appearance. In fatty degeneration it loses its contractility and shows fat in a free state amongst changed structure elements. In death from carbonic oxyde it has a red florid colour due to the combination of the poison with its hematocrystalline; in tetanus it is spasmodically contracted, changed, and frequently torn; in hydrophobia it is similarly injured and torn; in trichiniasis it is the specific seat of a parasite, the trichina spiralis, which does not live in any other tissue. The changes of the muscles in diseases have only just begun to be studied, and cannot fail to be found of the utmost importance.

Diseases in muscles.

As the muscle during life takes up oxygen from the blood, besides nutriment of the most varied kind, and renders back to the venous blood carbonic acid, water, and a host of refuse matters, so does the dead muscle, its coagulated myosine notwithstanding, continue some time to breathe, take up oxygen and give out carbonic acid. At last its atoms take a new direction, and physiolysis or putrefaction commences. The muscle yields the products common to the albuminous substance, tyroine, leucine, volatile acids and alkalies, &c. The same substance is obtained by chemolysis; leucine was first discovered (by Braconnot) in the decomposed muscular tissue. By continuing the study of chemolysis we shall probably be able to learn more about the changes of the muscles in disease, as well as about the ingredients of flesh extracts which are at present unknown.

Dead muscle.

Physio- and chemolysis of muscle.

The smooth or organic involuntary muscular fibres contain some ingredients similar to those of the striated, but require to be better studied—a matter of great difficulty, as they cannot easily be isolated.

Involuntary muscles.

The nerves and brain consist mainly of minutely thin long fibres, and of cells standing in connexion with these fibres. These fibres are membranous tubes, filled with a peculiar nerve or brain marrow. When the nerves are taken out of the living body they change quickly, and the marrow of the tubes separates into two substances—a central one, the cylinder axis, and an outer or periaxial portion. This change is not yet quite explained. Possibly it may consist in a coagulation of the axial cylinder, which causes its contraction. The axial cylinder is, however, already in life of a different chemical composition than the periaxial tube, for it shows no effects in the polariscope, while the periaxial part exhibits dark or light crosses. The chemical constitution of these matters is perhaps the greatest problem of organic and physiological chemistry. A consideration of all researches since the time of Vauquelin tends to show that brain matter is constituted similar to the hematocrystalline of the blood; that it contains an albuminous matter to which is combined a substance containing nitrogen and phosphorus; that its molecule must therefore be very complicated and large, and that the matters hitherto extracted from the brain are at the most detached proximate nuclei, or single stones broken out of the mosaic picture which its molecule may be imagined to represent. The principal one of these detached nuclei is a body of which a small quantity can be extracted from brain matter by boiling alcohol, and which has been variously termed brain-wax, brain-fat, cerebrine; but by Frémy, who first obtained it pure and determined its composition, was found to be an acid, and termed cerebric acid. Lately Liebreich, having examined the

Ingredients of the brain and nerves.

Brain-fat, cerebrine, cerebric acid, protagon.

same substance, gave it the name of protagon, but without any valid reason. This cerebric acid has the empirical formula of $C_{116}\ H_{240}\ N_4\ P\ O_{22}$. It appears in crystalline needles, and gives remarkable reactions, of which several new ones will be described in a subsequent paragraph. By decomposition it yields fatty acids, glycero-phosphoric acid ($C_3\ H_9\ P\ O_6$), containing the whole of its phosphorus, and neurine ($C_5\ H_{13}\ N$), containing all its nitrogen. Much of it is contained in the brain in a state of such firm combination that even concentrated sulphuric acid does not easily set it free. There is further in the brain cholesterine, the peculiar alcohol of which a quantity is constantly excreted with the bile. The albuminous substance of the brain has not yet been isolated completely; a small quantity can be extracted as potash-albumen (or caseine); another quantity is insoluble in water, and its presence can only be deduced from the curdling of brain matter by boiling, and from the products of the chemolytic process, which, as I have found by researches to be alluded to, yields all the products of chemolysis of albuminous matter, volatile acids and alkalis, leucine, tyroine, and other substances. Of other matters there are found in the brain substance lactic and a volatile acid, and inosite; uric acid, xanthine and hypoxanthine; creatine. Sugar is sometimes found, and more rarely a substance which gives reactions similar to starch, and the study of which may perhaps throw some light on the peculiar disease termed amyloid degeneration. In diseases, leucine and a homologue of it appear sometimes. In others much urea collects in the brain and in the cerebrospinal fluid, which fills the cavities of the brain and spinal marrow. The largest quantities of urea are met with in cholera, in which the cerebrospinal fluid may contain as much as ordinary urine. In a case of softening of the brain Lehmann found glycero-phosphoric acid in the softened matter. The brain substance contains 25 per cent. of solids only, and 75 per cent. of water. Its ash contains acid phosphates and a quantity of free phosphoric acid, a residue of the destroyed cerebric acid. Besides much potassium, some sodium, little magnesium and calcium, the ash always contains a notable quantity of iron. The ash of the grey matter of the brain is always alkaline, owing in part to the circumstance that it contains less cerebric acid than the white matter. When an ethereal extract of brain matter is mixed with water, and seen under the microscope, it swells and projects various peculiar forms of matter in various directions. The phenomenon is due to cerebric acid, which is dissolved in soap; it has given much and varied amusement to microscopists.

Fatty acid, glycero-phosphoric acid, neurine.

Cholesterine.

Caseine, albuminous matter.

Various ingredients.

Ash.

Myeline.

The connective tissue forms tendons, fasciæ or envelopes of muscles and limbs, ligaments of joints and capsules, and binds all organs of the body together. It consists of fibres, of a cement uniting these to a tissue, of cells or so-called corpuscles, and is interspersed with elastic fibres. It is soaked with potassium-albumen. The cement is soluble in caustic lime and in baryta-water; it is reprecipitated by acetic acid, and then manifests itself as mucine, identical with that of the salivary glands and embryonal tissues, *e.g.*, the umbilical cord; the fibrillæ remain isolated, but mixed with the corpuscles or cells and their nuclei, and with elastic fibres. In acetic acid the fibrillæ are transformed into glutine or glue. The same transformation is effected by prolonged boiling in water. The elastic fibres resist this treatment. Both sorts of fibre by chemolysis yield tyroine, leucine, volatile acids, and alkalies, but the gelatine is distinguished by yielding glycocoll, the lower homologue of leucine, while elastic fibres yield more leucine. Mucine yields sugar by chemolysis, and in this respect resembles chondrine, but it also yields much

Connective tissue.

Cement mucine.

Gelatine or glutine.

tyroine, up to 7 per cent. These various data have given rise to the idea that mucine and glutine were products of a peculiar cleavage of albumen, but albumen has not yet been found to yield any sugar. The cells or corpuscles of the connective tissue consist of a semi-fluid matter which is termed the protoplasma, and of nuclei. In the protoplasma of the cells of the connective tissue pigment is frequently deposited (choroid, rete Malpighii of negro, bronzed skin disease, freckles, melanotic cancers,) which is black or brown. Of this pigment very little is known, but my researches promise to throw some light upon its nature and origin.

Protoplasma.

Pigment.

The fat tissue is made up of cells, in the interior of which fat is deposited, and of connective tissue. The fat cells are probably peculiar organs, but the cells of the connective tissue above described are probably able to deposit fat within their substance under certain circumstances. Some fat tissue remains permanently in the body, some may lose its fat during starvation or disease, and regain it. The fats in the human fat tissue are mostly those described in the paragraph on digestion, tri-stearine, tri-palmitine, and tri-oleine. The fatty tissue is subject to hypertrophy, or excessive infiltration; there also peculiar colorations are observed in several diseases, *e.g.*, consumption or phthisis. Newly formed fat tissue is observed in the fatty tumours or lipomata. Fat in tissue may originate in several ways; it may have been eaten with the food, and after absorption only been carried to the cells; or it may be formed from sugar, dextrine, and glycogen; or, lastly, it may owe its existence to the decomposition of albumen. Thus the cholic acid of bile might easily yield any of the fatty acids, and sugar the glycerine. But the proofs for any of these processes have not yet been furnished.

Fatty tissue.

Fatty tumour.

Cartilage contains peculiar cells and chondrinogen, or a substance which by boiling becomes chondrine. This matter gelatinises like gelatine, but is not soluble in acetic acid, on the contrary precipitated by it. Boiled with hydrochloric acid, chondrine yields sugar.

Cartilage.

The chemical composition of the cornea is similar to that of cartilage, particularly the hyaline variety.

Cornea.

The cartilages are subject to a degeneration which terminates in ossification.

Ossification.

The cartilage surfaces of joints are lubricated by a fluid which is termed synovia. It contains about 94 per cent. of water, 3·5 of albumen, 0·5 of mucine, and more than 1 per cent. of ash. Its origin is not yet satisfactorily explained. During diseased conditions of joints much synovia can be detected; the collection of excess of synovia in a joint constitutes hydrarthron.

Synovia.

Hydrarthron.

A matter similar to chondrinogen is hyaline, of which the cysts of old echinococci are composed. Boiled with dilute sulphuric acid it yields, like the chitine of insects and articulate animals ($C_9 H_{15} N O_6$) dextrose fermentescible sugar.

Hyaline.

The bones consist of a peculiar combination of organic matter with mineral earthy phosphates, and contain as accessory matters marrow, bloodvessels, and cellular nuclei in the cavities called bone corpuscles.

Bones.

The organic substratum is called osseine (a name which it would be better to apply to the entire bone tissue), the mineral matters are termed bone-earth. The osseine is obtained by extracting the bone-earth with dilute hydrochloric acid. It retains the structure of the bone substance, which is disposed in concentric layers round a tubular centre. Osseine dissolves on boiling in water like glutin, but differs from the latter in several particulars, although the product of the solution in hot water is true gelatine. Of osseine purified bones contain from

Osseine.

29·5 to 30·9 per cent., with which 68·1—69·4 per cent. of earthy salts are in combination. The regularity of these proportions has led to the assumption that bone is a chemical compound in definite atomic proportions of osseine and earths, and not merely a tissue in which earths are deposited. Some remarkable experiments show that gelatine and earthy phosphates have a peculiar attraction for each other. Thus a mixture of gelatine and bone-earth in hydrochloric acid, when neutralised by ammonia, deposits bone-earth with 20 per cent. of gelatine; vice versâ when tannic acid is added to such a solution tannate of gelatine with much bone-earth is precipitated. Bone-earth contains 9·1 per cent. of calcium carbonate, 87·7 of calcium phosphate ($3\,\overline{Ca}\,P_2\,\overline{O}_8$), 1·7 of magnesium phosphate ($3\,\overline{Mg}\,P_2\,\overline{O}_8$), and 3 per cent. of calcium fluoride ($\overline{Ca}\,Fl_2$). The nutrition of the bones proceeds from their surface towards their cavities. Certain dyes, given with the food, penetrate into the bones and stain them. The idea formerly combined with this experiment, namely, that the bone was rapidly renewed from without and absorbed in the marrow cavity, is probably quite untenable. In several important diseases the bones are greatly affected, and become either brittle, or soft and bend. Such diseases are rhachitis, or rickets, common in children, and the osteomalacia of pregnant women, and that particular form which attacks aged persons. In these diseases the bone-earth falls to about 30 per cent. of the dry bones, while the osseine rises to 60 and 80 per cent. The osseine at the same time changes its chemical character, by a curious tissue transformation, starting from the marrow cavities, and does no longer yield glutine. It seems that the agent by means of which in this no doubt complicated process the earths are removed is lactic acid, which under these circumstances, and not in health, is found in and about the bones. These diseases urgently call for chemical investigation.

Bones dyed with madder.

Rhachitis.
Osteomalacia.

Lactic acid in bones.

Teeth.

The teeth are bones, of which a part, the root, is constructed like ordinary bone, the top or crown upon a particular plan, round many minute tubes; this latter tissue is termed dentine. The outer hard covering, the cement, is an epithelial formation, containing only 4 per cent. of organic matter, 92 per cent. of earthy phosphates, and 4 per cent. calcium fluoride.

Dentine.
Cement.

Pus.

Pus is a product of disease or injury. It consists of a serum, in which many corpuscles, resembling the white corpuscles of the blood, are suspended. From the corpuscles, separated by filtration, myosine (see muscles) is obtained. This substance is probably the instrument of the contractility of these bodies. The serum has fibrino-plastic properties, *i.e.*, contains paraglobuline, which can be precipitated by carbonic acid; on addition to the filtrate potassium albuminate or caseine is precipitated, and after the removal of this latter serum albumen is precipitated by heating. Mucine has never been found in pus. Chondrine and glutine have been found in the filtrate from the pus coagulated by boiling. They are probably connected with the corpuscles, like the glutine which is found in the blood in leukocythæmia. Pus, probably in its corpuscles, contains cerebric acid and cholesterine; the latter is deposited on standing. During standing and decomposition pus also deposits palmitic and stearic acid in crystals, oleic acid after addition of acetic acid. Good or healthy pus from wounds contains no volatile acids, but decomposing pus yields volatile acids of the fatty series, formic, butyric, valerianic, in short products of putrefaction. Pus from abscesses, from phosphorus disease, and ulcerating cancers, contains an acid, which as it gives a rose-pink reaction with chlorine

Myosine in corpuscles.

Paraglobuline, caseine, and serum albumen in serum.

Chondrine and glutine.

Leukocythæmia.
Cerebric acid.
Cholesterine.

Fatty acids.

Volatile fatty acids.

water, has been termed chlorrhodinic acid. A similar substance can be obtained from decomposing pancreas extract and lymphatic glands. Pus may contain leucine, tyroine, xanthine, and uric acid ; in the pus from jaundiced persons biliary acids and cholophæine are found; in that from diabetic patients sugar. The so-called blue pus derives that colour from a kind of vibrio, which yields its pigment to chloroform, from which it is obtained in crystals, and termed pyocyanine. The solid matters contained in pus amount to from 10 to 15 per cent.; its ash is similar to that of blood, contains 72 per cent. of sodium-chloride, and more potassium-salt than blood-serum. A knowledge of the composition and products of decomposition of various kinds of pus from abscesses, ulcers, wounds, &c., is of the utmost importance for the study and treatment of reactive fever after wounds and operations, of various forms of blood disease termed septichæmia, and pyæmia. In all these affections pus, or products of its decomposition, are absorbed or enter in a more grossly mechanical manner into the lymph and blood, set up an acute patholytical process which leads to violent attacks of shivering, fevers, sweating, diarrhœa ; then, in the case of septichæmia and pyæmia to secondary deposits of pus or other fluids in various organs and cavities, particularly the lungs and liver, and ultimately, and in nearly all cases, to death. Against this fatal disease a particular kind of treatment of wounds, the so-called antiseptic treatment, has lately been devised, and is now under the consideration of surgeons.

Chlorrhodinic acid.

Blue pus.

Pyocyanine.

Pyæmia.

The function of the spleen is not well known, but seems connected with the elaboration of certain constituents of the blood and certain processes of digestion. The organ contains much blood, and a separation of its tissue and juice from its blood has not yet been effected. The fresh spleen is alkaline, but soon becomes acid. The watery extract contains hematocrystalline and the other ingredients of blood, and besides a peculiar albuminous matter which on combustion leaves phosphoric acid and iron oxyde. It encloses some cholesterine. After removal of all albuminous matters there are in the extract of fixed acids the lactic and succinic, of urinary products hypoxanthine, xanthine, and uric acid, of volatile fatty acids formic, acetic, butyric, of amido-acids leucine ; of alcohols there is inosite in considerable quantity. These ingredients show that chemical processes of various kinds must be carried on actively in the spleen. They are, however, not indispensable to life, as animals from which the spleen has been removed by operation continue to live without any perceptible disturbance. In leukocythæmia the spleen is frequently very large, and weighs up to nine and ten pounds. If it be found small in that disease the lymphatic glands are certainly enlarged. The spleen is sometimes subject to (here) mis-called amyloid degeneration. Although in this state it gives many reactions of albumen it is indigestible in artificial gastric juice ; it gives no sugar by treatment with sulphuric acid, and is little prone to change by artificial or natural influences.

Spleen.

Peculiar matter.

Ingredients of water-extract.

Waxy degeneration of spleen.

The thymus gland is a mysterious organ situated in the chest in front of the lungs. It becomes of less importance to the adult than it probably is to the fœtus "in utero." It contains albumen, collagene, elastic tissue, a little fat, leucine, xanthine, hypoxanthine, succinic and lactic acid, and perhaps also volatile fatty acids and sugar. In the progress of the involution of the thymus the amount of sodium contained in it is nearly doubled.

Thymus gland.

The thyroid contains nearly the same chemical constituents as the thymus. It would be very confusing that the constituents of glands of the most varied connection and situation are identical, were we not reminded that the defined ingredients are perhaps only one-fourth or

Thyroid.

one-sixth of the whole of the ingredients, and that specific differences may therefore be discovered upon the ingredients which at present are undefined. The thyroid is said to contain mucine, particularly when in the state termed colloid degeneration ; it then also contains cholesterine. When containing brown fluids, in the disease termed struma, a sediment of blood corpuscles is mostly present, which, however, contain only decomposed hematocrystalline in the form of hematine.

Suprarenal capsules.

These organs yield many curious coloured reactions. Their alcoholic or ethereal extracts become yellow and red when exposed to the air ; their watery extracts are coloured red by iodine, and blackish blue by iron-chloride. They contain leucine, but the presence of other particular biliary matters which has been alleged is at present not proved. In certain chronic diseases (Addison's disease, or bronzed skin), in which the skin is more or less copper or brown-coloured, the suprarenal capsules are specifically diseased. A case of this disorder is now under special investigation.

Salivary glands.

The salivary glands contain mucine and leucine, xanthine and hypoxanthine.

Pancreas.

The pancreas contains much leucine, a homologue of it, xanthine hypoxanthine, and guanine. Also some of the ferments mentioned in the paragraph on digestion can be extracted from its pulp as well as from its juice.

Liver.

The liver consists of cells, which are the main seats of its specific function, and of bloodvessels and bile ducts, interspersed with lymph vessels and nerves. The blood can be washed out by water. The cells are made up of a protoplasma, which may contain as visible ingredients fat in large and small granules, cholophæine in small red granules, nuclei, with one or two corpuscles, and as invisible ingredients demonstrable by experiment only, a coagulable matter which sets soon after death, albumen, mucine, and glycogen. Sugar and biliary acids are also always obtained from the extract of the liver, although the ducts may have been carefully washed out; and as cholophæine is contained in the cells, we may assume that the bile acids are also contained and made in the cells. The fresh liver is always alkaline, but on standing it becomes acid. The glycogen is mostly or entirely transformed into sugar. The liver-extract by boiling water mostly contains lactic acid and volatile fatty acids, inosite, hypoxanthine, xanthine, and uric acid, and leucine. The latter body occurs in livers which are quite fresh, in very small quantity, but increases by decomposition, for which the tissue of the liver or its cells possess particular aptitude. Fat is extracted from most livers, in large quantities from diseased livers. Tyroine occurs in diseased livers only, and is not easily obtained even from thoroughly putrid livers. In the ash of the liver phosphoric acid and potassium predominate, which is the more to be noted as the bile acids in man are mainly combined with sodium. From fresh livers of young persons and animals hydrogen

Waxy liver.

is sometimes evolved on immersion in warm water. The degeneration of the liver, which is sometimes wrongly called amyloid, or otherwise the "Speck-leber" of the Germans, and "waxy degeneration" of the English, has not any resemblance to the amyloid degeneration of the spinal marrow : for iodine and sulphuric acid, or iodine alone, produce in it only a red or reddish-brown mahogany-like coloration, its material being evidently of an albuminous kind : and on extraction by alcohol and ether, I have found in it considerable quantities of cholesterine, fat, and paralbumen, but neither bile nor sugar. Having during many

Leucine, special method for isolation.

years, and in many cases, observed considerable quantities of leucine in the liver, and having frequently experienced great difficulty in

isolating this substance, separating it from others, I subjected to a special study the compounds of leucine with metals, and was happy enough to discover a new copper compound which renders leucine entirely insoluble in water and neutral fluids. For the extraction of hypoxanthine and xanthine I have also devised special processes.

The kidneys contain much blood, collagene fibres, and some fat; to water extraction they yield chlorrhodinic acid, uric acid, and bodies resembling hypoxanthine and xanthine, but urea is scarcely obtainable from them. Cystine and inosite have on some rare occasions been met with. The chemical changes of the kidneys in diseases have not yet been sufficiently examined. Kidneys.

The urine is the secretion of the kidneys. It is the lixiviated refuse from the chemical processes of the body. It contains a yellow colouring matter, urochrome, which by chemolysis yields various remarkable products of decomposition. The first is uromelanine, $C_{36}\ H_{43}\ N_7\ O_{10}$, a most interesting substance, with an atomic weight of 733, being one of the highest at present established in organic chemistry. Accompanying uromelanine there is a small quantity of a matter which by treatment with sulphuric acid yields the reaction and spectrum of cruentine, termed paramelanine. The next product is uropittine, not as yet sufficiently studied. Then there is omicholine, an organic base with fluorescent properties and a peculiar spectrum, and omicholic acid, also fluorescent, but slightly differing in its spectrum and composition from omicholine. Of these matters I shall have to speak in subsequent paragraphs. From these products it is evident that urochrome must possess a very high atomic weight; it may perhaps be a derivate of hematocrystalline. The ingredient which occurs in urine in the largest quantity is urea, $C\ H_4\ N_2\ O$, of which a man secretes about 30 grammes in 24 hours. Then there is creatinine $C_4\ H_7\ N_3\ O$ the same as that which occurs in the muscles. It is partly changed into creatine, $C_4\ H_9\ N_3\ O_2$, by taking up an atom of water during the process of preparation. From creatinine is derived sarkosine, which is isomeric, or perhaps identical with alanine $C_3\ H_7\ N\ O_2$. There is further contained in urine uric acid, $C_5\ H_4\ N_4\ O_3$, which may form calculi and cause much trouble, and a series of bodies being less oxydised than uric acid, namely, guanine, $C_5\ H_5\ N_5\ O$, hypoxanthine $C_5\ H_4\ N_4\ O$, and xanthine $C_5\ H_4\ N_4\ O_2$. Further, there is an acid which from having been first discovered in horses' urine is termed hippuric, $C_9\ H_9\ N\ O_3$, remarkable by its consisting of a combination of glycocoll, $C_2\ H_5\ N\ O_2$, and benzoic acid, and by its being found in considerable quantity in the human body when benzoic acid is being taken, or greengages are consumed. Under some circumstances allantoine appears, $C_4\ H_6\ N\ O_3$, which can also be produced from uric acid artificially, along with other remarkable products. Of inorganic salts the phosphates of lime and magnesia, and of potash, are present in considerable quantity, but most prevalent is the sodium-chloride or common salt. Of some matters minute traces appear in the urine, thus of sugar and of alcohol, after these bodies have been taken by deglutition. In diseases there may appear blood, albumen, fibrine (paraglobuline and fibrino-plastic matter) fatty acids and fats, large quantities of sugar, as in diabetes, leucine, tyroine, abnormal coloured matters yielding by acids urocyanine and urorubine, as in cholera; oxalic acid and oxalate of lime, as in a particular disease which frequently ends in the formation of calculi. Much as the urine has been studied its chemistry is by no means accomplished,

The urine.

Uromelanine.

Uropittine.

Omicholine.

Omicholic acid.

Urea.

Creatinine and creatine.

Sarkosine.

Uric acid group.

Hippuric acid.

Allantoine.

Salts.

Sugar, alcohol.

Pathological ingredients.

and on the causes of the most troublesome diseases showing themselves by symptoms in the urine, gout, uric acid calculus, oxalic diathesis, diabetes, chylous urine, our knowledge is as yet very incomplete.

Under all circumstances, however, the analysis of the urine is an indispensable aid to clinical diagnosis, and furnishes most valuable positive and negative information on acute as well as chronic diseases.

Sweat, Lactic and sudoric acid.

The secretion of the skin, discharged in large quantities after exertion or under the influence of a heated atmosphere, contains much surface epithelium. Of chemical ingredients there are observed lactic and sudoric acid, the latter peculiar to sweat and not found anywhere else, and urea. There is much sodium-chloride, little or no phosphate. Sometimes volatile fatty acids–*e.g.* valerianic, are found in small quantity, but it is possible that they are formed after the sweat has been secreted.

Breath.

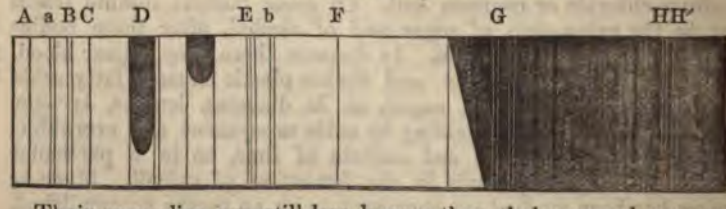
In respiration oxygen of the air inhaled together with its nitrogen is absorbed by the blood, and in exchange carbonic acid and water are given out. The expired air therefore contains less oxygen than the inspired, and a quantity of carbonic acid instead. But the whole of the oxygen inhaled does not return as carbonic acid and water ; a portion is otherwise combined and leaves the body in the urinary products of oxydation, particularly urea. A healthy strong man exhales in 24 hours upwards of 400 litres of carbonic acid, and inhales upwards of 500 litres of oxygen. The expired air during rest contains about four volumes per cent. of carbonic acid. During activity the expiration of carbonic acid becomes much more rapid, and in extreme cases may for a short time rise to tenfold its normal quantity in the same time. Activity or muscular work does on the other hand hardly increase the quantity of urea excreted by a man.

The breath in diseases may contain carburetted hydrogen (of which a trace is also excreted in health) and volatile matters at present unknown, ammonia being perhaps amongst them. These investigations have only just become possible by the invention of an apparatus which permits entire persons to be observed for days in glass chambers, and their excretions to be accurately analysed and determined. By means of this method it has now been found that man during sleep stores up a quantity of oxygen in his body, particularly his muscles, which is therefore ready for the production of force the moment it may be wanted. This explains the phenomena of activity and rest much better than they could hitherto be defined.

Fæces.

The fæces contain all insoluble residues of the food, some decomposed and altered bile acid, changed cholophæine, myochrome, cholesterine changed into excretine, some peculiar fatty and odoriferous matters, besides a little phosphate of magnesium and calcium. They vary with the diet, being dark, semifluid, and of small bulk after meat diet, but of large bulk, paler and more solid, after bread diet. Boiled with sulphuric acid they yield a matter which has the spectrum represented in fig. 1, plate III., and of which the accompanying engraving is a diagram.

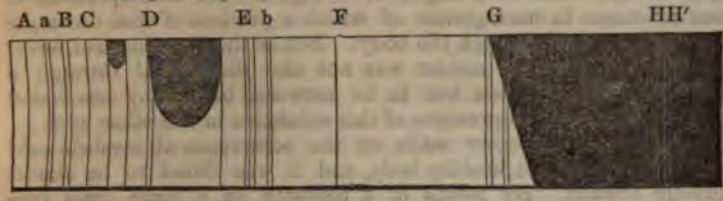
Stercorine in Sulphuric Acid.



Their anomalies are still less known than their normal composition. The cholera evacuations were fully described in my report on cholera.

But I here insert an amended diagram of their spectrum, which may be compared with stercorine on the one, and acid cruentine on the other hand.

Diagram of Spectrum of Fermented Cholera Stool.



Iron preparations taken into the stomach colour the fæces black, mercurial ones green. This latter fact gave rise to a fallacy now exploded, namely, that mercury was a cholagogue and increased the excretion of bile. Bile (not decomposed) has never yet been found in any fæces. Most remarkable and suggestive is the discovery by Liebig of alloxan in the mucous evacuations from a case of intestinal catarrh. Alloxan is a product of decomposition by oxydants of uric acid, and precedes the formation of urea. Possibly, therefore, functions of chemolysis are allotted to the intestine which at present we place into other organs, or know not where to localise. Gout might find an explanation in the failure of this chemolytic action, for uric acid once in the blood seems as far out of the reach of oxygen as sugar in the blood is in diabetes. Imperfect digestion further causes the production of gases, of which carbonic acid constitutes the main bulk, but is mixed with combustible marsh-gas, $\mathfrak{C}\,H_4$, and some hydrothion $\mathfrak{S}\,H_2$. This development in diseases rises to painful height, and in typhus, *e.g.*, produces sometimes an almost suffocating tympanites or meteorismus.

Alloxan in mucous evacuations.

Gases in intestines.

III.—Illustrations of the Tentative Nature of the Researches.

For reasons which need not here be detailed I began the present series of investigations by some inquires concerning Tetanus. The descriptions of this disease which had been given by surgical writers represented it as so much resembling poisoning by strychnia, that one was almost compelled to suppose that in its progress a chemical decomposition took place by which a body being either strychnia itself, or having almost identical properties in relation to the human frame, was developed, and I therefore put the question whether this body could be extracted from the organs of persons who had died from tetanus. I made extracts from a great variety of organs from the bodies of six patients who had successively died of that disease. In none of the cases was any strychnia met with; but what was as singular was, that although these persons had up to the time of death been taking large doses of morphia, partly by injection underneath their skin, partly by deglutition, none of their organs showed any sign of the morphia taken.* But from all the organs, and from the blood, matters were always extracted of which some appeared to possess the qualities of known substances, while others manifested themselves by new properties as bodies hitherto unknown. It now became necessary to identify those bodies which appeared to be known.

Tetanus.

* The slight solubility of morphia in ether, amounting almost to insolubility, was of course considered, and the processes and reactions were accordingly modified.

Most important among them appeared a substance having many of the properties of a well-defined substance obtained from the brain, namely, cerebric acid. In view of the circumstance that tetanus had always been referred to a lesion of the nerve system, suspicion arose that the presence of this brain-acid might be a sign of the decomposition of nervous substance in consequence of which a product of that decomposition was distributed through the body. But as the question had never been asked whether this matter was not also distributed through a healthy body, this question had to be answered before any conclusion could be drawn from the presence of this substance in the other case.

Cerebric acid.

Cerebric acid present in organs and blood corpuscles.

A research was therefore made on the occurrence of cerebric acid in various parts of the healthy body, and it was found to be almost universally present. By means of a research on a large scale concerning the chemistry of the blood corpuscles, it was ascertained that cerebric acid was also an unfailing essential constituent of the blood corpuscles. When, in continuation of the research on tetanus, the brains of the victims of the disease were subjected to chemical examination, and the results compared with the ordinary teaching of science, it was found that that teaching was either erroneous or incomplete. Even the existence of cerebric acid, which had been discovered by Frémy, had been disputed by Liebreich; and the researches of Liebreich had been controverted just a few months before by Köhler, who had spent no less a time than three years over his subject. It was therefore necessary for me to institute for my own guidance some preliminary experiments on the question of the constitution of the brain matter. Those preliminary researches are far from complete, but every step of them has yielded a reliable and new result, confirming in the main the teaching of Frémy, and establishing that between Liebreich's protagon and Frémy's cerebric acid the difference is more in name than in substance. I found, however, also, that none of these observers had even touched the question of the constitution of the brain matter; and that there was in this latter a nucleus of power holding together a chemical molecule of immense size which could not be separated by any of the re-agents employed by former observers. I therefore proceeded to split up this molecule by the process of chemolysis. By this research it was found that the brain matter yields all the substances described by Gobley, the cerebric acid of Frémy, the protagon of Liebreich, leucine, tyroine, a number of volatile alkalies—among them trimethylamine, three fluorescent bodies and an amorphous acid to be alluded to in the chapter on the albuminous substances, and to be more fully investigated hereafter; and, beyond that, left a residue which resisted even the chemolytical process, hitherto supposed to split up all animal matter. Thus it was clear that brain matter possesses a constitution which is of the utmost complication, and that means must be found to determine the size of its chemical molecule, and that these means cannot be exclusively the process of chemolysis, and subsequent calculation by synthesis of the results, but that it must be of a more direct kind.

Researches of Frémy, Liebreich, and Köhler.

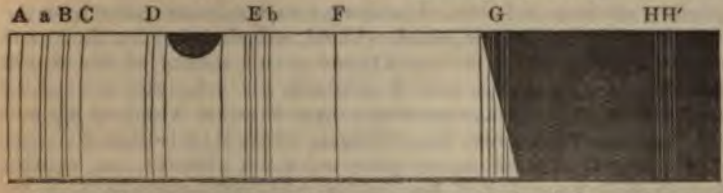
Chemolysis applied to brain matter.

These researches left me the impression that the constitution of brain matter possesses some analogy to the constitution of the blood corpuscles, in this respect, that its basis is a body which contains phosphorus, nitrogen, carbon, hydrogen, and oxygen, and may be transformed into or appear in the shape of cerebric acid; that this body possesses originally the properties of a polydynamic alcohol, which is combined with a number of molecules of albumen corresponding to the number of its dynamicities.

Returning to the comparison of the matter found in tetanous organs with that produced from healthy brains, I ascertained some new and

characteristic tests for that matter. Cerebric acid with sugar and sulphuric acid yields a magnificent purple colour, which is in every respect more striking than the colour which, with similar re-agents, is given by the biliary acids. I determined the spectrum (see Plate III. fig. 5) of the coloured product, and compared it with the spectrum of the coloured product obtained by this reaction from bile acids, and found them not to be identical.*

Cerebric Acid and Pettenkofer's Test.



Fluorescent bodies.

On continued scrutiny of the extracts obtained from the tetanous organs, substances were found which possessed the remarkable property of *fluorescence*. This was the more interesting as it had lately been announced by Drs. Dupré and Bence Jones that there occurred in all healthy structures a fluorescent matter to which, from its similarity to quinine, they gave the name of "animal quinoidine." The matter extracted from tetanous organs did not respond to the tests of animal quinoidine; although, behaving as an organic base, its optical properties were different from animal quinoidine, with genuine specimens of which it was assiduously compared. Owing to the small quantity of this substance, and to a deplorable accident which occurred to even that small quantity by an incipient conflagration in the laboratory, the nature of this substance had to be left undecided.

Fluorescent substance not found in a case of paraplegia.

On examining, for the purposes of comparison, the organs from a case of paraplegia, the fluorescent body could not be met with. The cerebric acid was found in the blood and other organs, and, for the rest, it was clear that in this case the lesion was a mechanical one—that chemical consequences were secondary, and the study was therefore not prosecuted any farther.

Fluorescent matter in cholera extracts.

After the completion of the research on cholera (published in the last report of the medical officer), the whole of the extracts from upwards of a hundred organs, from more than twenty different cases, from which the matters described in that report had been extracted, were united. They were found to contain considerable quantities of the peculiar fluorescent matter which had been first met with in tetanus. As the investigation of the whole process of cholera had led to the discovery that there was, at one period of it at all events, a decomposition of

* Vitelline from yelks of eggs with sulphuric acid alone yields a spectrum which differs somewhat from that of cerebric acid. It is here subjoined. See also Plate III. fig. 4.

Vitelline in Sulphuric Acid.

albuminous substances in the intestine, very similar to putrefaction, as evidenced by the presence of leucine, valerianic acid, butyric acid, acetic acid, volatile alkalies, and so forth, I was led to surmise that the presence of this fluorescent body in the tissues might possibly be caused by the putrefactive decomposition, and that, inversely, the presence of that body might be the sign of the presence of a change akin to putrefaction. It therefore was necessary to subject to an examination in this respect the normal substances which constitute the tissues and fluids of the human body; and I selected, in the first instance, the process of chemolysis as the quickest and most suitable. I instituted an extensive research on the chemolysis of fibrin, albumen, caseine, blood, and almost every tissue and organ of the human body, the main features and results of which will be described in chapter V.; and I obtained not only products which had been obtained by former observers since Braconnot and by my own former researches, but I also was fortunate enough to isolate six compounds, a portion of which were quite unknown hitherto, and another portion, though known, not having been hitherto discovered in the course of this process. Among them was the fluorescent body which I had met with in the extracts from tetanus.

New compounds obtained by chemolysis of albuminous bodies.

Products of chemolysis.

I state here the conclusion at which I at once arrived, and which I do not think can be questioned by the calmest consideration. Whether the fluorescent body extracted from tetanus-organs, and which is probably the same as that obtained by chemolysis from albuminous matters, including the brain, has any causative influence in the production of the tetanic symptoms, or is itself a mere symptom or accident of the process, a practical advance can be made upon the theory of tetanus by the study of the fluorescentine obtained by chemolysis. The continuation of these researches, being contingent upon the occurrence of cases in an available form, is for the time interrupted. No doubt in other cases other questions may arise, and many of them are as present to my mind as those which I have already endeavoured to answer. That there is in tetanus the most rapid change which occurs in any disease whatever is shown by the enormously high temperature which we observe in that disease. In no other disease does the body reach the temperature of 44 degrees centigrade; and in those diseases in which we observe the next high temperatures, namely, typhus fever, typhoid fever, yellow fever, and others, the limit of 42 degrees is never exceeded without fatal results.

Hydrophobia.

The next disease almost as fatal as tetanus, which engaged my attention, was hydrophobia. I instituted a microscopical examination of the spinal cord of some cases, according to the latest and most approved methods, without finding any lesion perceptible by the microscope. On turning my attention to the blood, I was struck by a slight change in the spectrum; but it was impossible in the then state of affairs, and with that low degree of perfection in the measuring apparatus of the spectroscope, to give to that observation a scientific precision. It led me, however, to a comparison of the red coloured part of the blood with the red coloured part of the muscles; and as both in tetanus and hydrophobia the muscles are the field upon which the symptoms are most prominently exhibited, it appeared a fair question whether in either of those diseases there is an influence exercised by the blood upon the muscular system, or, inversely, by the muscular system upon the blood. The same question occurred during the cholera inquiry, when in cases of collapse and so-called asphyxia the muscular system was found of a dark, almost bluish-colour, and yielded a spectrum of reduced cruorine. It was in the interval between the cholera research and the former researches on the diseases mentioned that I discovered the

identity of cruorine and myochrome, the red coloured matter of the muscles. The physiological and pathological conclusions to which this newly-discovered relation led were very many and of immense bearing, for it was now established that neither of those two systems, the blood and the muscles, could escape the effect of the injury of either.

Typhoid and other febrile processes; their effect upon the muscles.

The loss of muscular power in the febrile process must clearly in part be the result of want of oxygen. For the peculiar products of the typhoid process for example, have a great affinity for oxygen, and circulating in the blood, abstract the oxygen for their own destruction before it has had time to reach the tissues. A muscle in typhoid fever is therefore in the same condition as a joint of meat hung up in an enclosed space without any ventilation. It was seen that gases which killed or injured by a specific effect upon hematocrystalline, such as carbonic oxyde, carbonic acid, sulphuretted hydrogen, and hydrocyanic acid, exercised their effect not only upon the blood but also upon all the muscles which are pervaded by blood, particularly the heart; and it became possible to suppose, in the case of cholera in particular, that the contraction of muscles, the painful cramps, were the result of diminished or altogether suspended oxidation. The most important change of the muscular system which takes place in typhus and typhoid fevers being regularly accompanied by a change of the natural colour of the muscle, I thought it necessary to make a research into the chemical nature of cruorine and myochrome. I began with cruorine. I precipitated it from blood on a large scale by means of carbonate of potash, and split it up into its constituents, albumen and hematine. I crystallized it in various ways, and compared its forms and phenomena of crystallization with those of its decomposition product hematine. I studied its spectra under the influence of a great variety of agents, medicines, poisons, and destructive bodies, and compared those spectra with a great number of spectra selected at random from similarly coloured bodies. I endeavoured to determine its atomic weight, and found it to be the highest of any among organic substances, and to amount to about 13,000. I then proceeded to investigate the phenomena of the crystallization of hematine. This latter is a product of the decomposition which blood undergoes not only by artificial chemical means, but also under the influence of physiological agencies when blood has been effused into cavities or tissues of the body. The crystallized hematine there found by means of the microscope has received the name of hematoidine. The crystallized compound, however, which was obtained from blood by a process employing acetic acid and common salt has been called hemine. It had been alleged that hematoidine was identical with the colouring matter of bile, and that the production of these hematoidine crystals in apoplectic cysts, in effusions of blood within the liver, and various effusions of blood in other organs—for example, the ovary, was evidence of the derivation from the colouring matter of blood of the colouring matter of bile. It had further been taught that hemine was not crystallized hematine merely, but a hydrochloric acid salt. Nothing could solve all these contradictory statements but an exhaustive research on the chemical nature of hematine. This I accordingly began, and was soon successful in obtaining a crystallized product having all the appearances of hemine, but not containing any hydrochloric acid, and yielding a little more than 7 per cent of metallic iron, thus indicating that the atomic weight of the hematine was upwards of 600. The spectra of hematine and of its products of decomposition by acids and alkalies were simultaneously determined. (See Chapter IV. 2. where most of the data evolved by this research are given.)

Hematine.

Hematoidine.

Hemine.

Spectra of cholera urine.

This research was of the utmost consequence in the explanation of some new phenomena which were observed upon choleraic urine. It will there be seen that an ingredient of the urine was discovered which, under the influence of nitric acid, was transformed into a blue matter, choleraic urocyanine, and into choleraic urorubine, and the spectrum of this latter almost completely coincides with the spectrum of hematine in alkaline alcoholic solution. Further researches will have to decide whether this apparent analogy can be allowed to be assumed as a proof of close connexion. There can be no doubt that the spectrometric method applied to this branch of the research will yet lead to most important developments.

Cholophaeine.

I had an opportunity of comparing hematoidine crystals with crystals of the colouring matter of bile which I obtained in my researches on that substance incidental on my researches on gall-stones. I thought it incumbent on me to follow out this subject farther. The colouring matter of bile seemed to require an independent study, on account of the important part which it takes in many acute fevers, accompanied by the discoloration of the surface of the body, and particularly in malignant acute jaundice or atrophy of the liver, and in the chronic diseases of that name. Moreover, it was a common ingredient of concretions, the nature of which I had investigated formerly, and I therefore proceeded to investigate its nature. I succeeded in determining its form of crystallization, and in showing that it was not identical with that of hematoidine. I determined its chemical composition to be $C_9 H_9 N O_2$. I determined its atomic weight, its properties, its transformations, and a great number of its compounds, and it was owing to my former researches upon this substance, and the circumstance that I had a collection of material at hand, that I was enabled to give to the research upon this subject that perfection which I should claim for every other substance which is to be considered in pathological chemistry. A full technical account of this research would not be entirely suitable for the present report; but in Chap. VI. (on the biliary substances) I have given a full abstract of the principal data.

General remarks on coloured ingredients.

The circumstance that hematocrystalline and certain ingredients of the bile and urine are coloured may with some persons have the effect of hiding their chemical and general importance; for as in general life colour is employed for ornamentation, and is not considered necessary for the essential qualities of things, the ordinary mind is liable to suppose that these coloured ingredients of secretions or fluids are also of no greater significance than dyes. But this is a great mistake. The circumstance that they are coloured is of advantage to science, inasmuch as the presence of such bodies has not to be discovered. They are patent to every eye; but the circumstance that they are coloured, and that with every change, even the smallest, of their composition they change their colour—to wit, the blood from light red in the arteries to dark red or blue in the veins—shows that colour here is associated with an essential property, the significance of which is a subject for the deepest study. The usefulness of this study on the colouring matter of bile appeared very strikingly during the research on cholera which has been published.

Reference to bile in cholera.

Here a number of biles from persons who had died of cholera were examined. Several of them were found free from all coloured matters. Several of them were found not to contain any biliary acids. One at least contained no biliary acids but coloured matters, and these coloured matters varied in several cases. There were present the four varieties, bilirubine, biliverdine, biliprasine, and bilifuscine. Now, whatever may be the significance of the presence or absence of these or other

ingredients of the bile in these cases, it is certain that the facts could not have been determined had not the chemical nature of the substances and their chemical reactions been previously determined by me.

Incidentally I may remark here that by attentive study of the records concerning yellow fever, and by personal experience concerning some forms of tropical disease in Europeans, I have come to the conclusion that the coloration of the skin experienced in those diseases is probably not caused by biliary matter distributed in the blood, but is due to decomposition of cruorine yielding products of which I may have to speak hereafter.

Hematocrystalline decomposes in yello fever and tropical fever.

During my investigations of the phenomena of the febrile process, I was struck with the small amount of positive information which was yielded by an analysis of the urine. Beyond an increase in the quantity of urea discharged in given times, and a diminution of the urinary water, no particular fluctuations in the quantity of the substances were observed, except the phenomenon known from time immemorial, that the febrile urine has a dark red, sometimes almost brown colour, and deposits matters which carry down with them a certain amount of those colours. The controversy regarding these matters has lasted as long as the research on them, until at last accomplished physicians have declared that these were matters not admitting of accurate chemical definition. I never shared that belief, and I continued to work through all difficulties, having at last the satisfaction of seeing my researches approved by the British Medical Association. The work then begun had now to be continued, and if possible completed, for without the knowledge of these matters a perfect theory of any febrile process whatsoever was quite out of the question. I therefore instituted a research on a very large scale, which absorbed many months of my time, and of that of several of my assistants, and I succeeded in establishing by the method of chemolysis a certain basis from which the chemistry of urochrome can in the future be solved with certainty. This basis is uromelanine, a product of decomposition of urochrome by putrefaction, as well as by artificial decomposing processes. This remarkable substance was found to have the enormous atomic weight of 733, being the highest among any decomposition products of the animal economy or of organic matters in general known. It was found to have a remarkable and varying combining power, so that no less than 19 combinations could be produced and analysed. I have subjoined an abstract of the principal data evolved by this research to the paragraphs relating to researches on the pathology of the urine (Chap. VII.). Besides uromelanine, I also analysed omicholine and uropittine. Omicholine was found to possess optical phenomena being the reverse of those of the green coloring matter of leaves, chlorophyll, for it had a port wine red colour, and in the cone of concentrated sunlight it fluoresced green, while chlorophyll, with its natural green colour, fluoresces red in the cone of sunlight.

Febrile proces variation of, excretions during.

Omicholine an uropittine.

While the researches on hematine had made it very doubtful whether there existed any connexion between the colouring matter of the blood and that of bile, and had shown that the assertion of former observers that the colouring matter of bile contained iron was unfounded, the researches on urochrome seemed to confirm the conception which former observers had formed of this matter being derived from cruorine by some process or other. Uromelanine could not be derived from hematine, unless indeed all the analyses of hematine hitherto made were first shown to be valueless. The atomic weight of hematine, even if the formula of Mulder were doubled to satisfy the demands of the theory of

the unitary notation, could not be much above 600, that of uromelanine actually is 733; by no calculation can the number of atoms of nitrogen in hematine be raised above six, while uromelanine unquestionably contains seven; hematine might therefore derive from uromelanine, but the reverse could if hematine be rightly understood never be the case. We have therefore but two possible cases. Either all the analyses of hematine hitherto made must be rejected, and supplanted by new and better researches, or, if they can be maintained, we must assume that uromelanine derives from hematocrystalline and not from hematine. From this it would further follow that hematocrystalline in its natural process of disintegration does not split up, as it does under the influence of acids and alkalies, into hematine and albuminous matter, but is by gradual oxydation transformed into an intermediate substance, which by the specific action of the kidneys is eliminated in the form of urochrome. Urochrome then would be hematocrystalline reduced to the limits of oxydisability and effete; of the great mass of albuminous substance only feeble traces are left in the shape of the nuclei, which after chemolysis appear as omicholine and uropittine. The great mass of what would have become hematine under appropriate conditions leaves the body in the form of the nucleus, which by chemolysis becomes uromelanine. The probable atomic weight of urochrome, which by the synthesis of its cleavage products is raised to about 1,500, fully supports these theoretical considerations.

IV. THE SPECTROSCOPE AND ITS APPLICATION IN PATHOLOGICAL CHEMISTRY.

1. *Generally, of the Spectroscope and its Uses.*

Origin of spectral observation. Prism a toy.

A triangular rod of glass has at all historical times been a toy in the use of which mankind delighted. For it was and is now the only generally applicable means by which the eye can at will enjoy the sensation of pure colours. Only two phenomena of nature offer opportunities for the same observation, the glorious rainbow and the polar aurora; the latter as awful as the former is consoling to the inhabitant of the moderate zone. The identity of the rainbow colours with those of the glass prism did not escape the eye of Seneca; and Vitellio, observing the same colours upon the rays of light which had passed through a glass of water, even made an unsuccessful attempt at their explanation. After Aristotle had shown the production of the rainbow colours upon a screen, this experiment remained for two thousand years a part of the scanty optical knowledge of philosophers. When Porta invented the dark chamber or "camera obscura," he facilitated the spectral observation greatly, and caused Kepler to attempt a long commentary upon it. Grimaldi discovered the elongation which the image experiences when the spectrum is formed. Marcus Marci was perhaps the first to describe the principal experiment with the glass prism in his "Thaumantias," but he arrived no closer to its actual theory than Ruini or Servetus to that of the circulation of the blood.

Spectrum projected on a screen. In "camera obscura."

Elongation of image by prism.

Different refrangibility of light gives colours.

Newton founded the science of optics by showing the nature of simple colours, which he defined as light-rays of equal refrangibility. The difference of colours was therefore based upon the different refrangibility of light. These discoveries he applied to the explanation of the variation of colours, of the natural colours of bodies, and to the explanation of

the rainbow. With the perfection of apparatus rose the means and the desire for more accurate observation. While Newton had mostly used a ray of light which entered through a round hole and was then broken up by a glass prism, Wollaston contemplated the prismatic picture projected by a sun-ray which entered the dark room or camera through a narrow slit. He thereby purified the spectrum and discovered (1802) black lines in it. He gave a drawing of five lines, besides the two terminals of his spectrum. But this discovery remained unused until Fraunhofer made it once more and established it as a new means for measuring phenomena of light (1817). He used the telescope for the examination of the spectrum, and discovered a great number of lines, the principal ones of which he appointed as standards of measurement for the several places and parts of the spectrum. During the first half of this century following the discovery of Fraunhofer, many learned physicists, particularly Sir D. Brewster and Sir John Herschel, studied the phenomena which were caused by the substitution of glowing solids or gases as sources of light in place of the sunlight, and by the interposition of fluids and solids on the path of the sun-ray before it reaches the prism. (Positive and negative spectra. Effects of absorption of particular rays.) The data thereby ascertained were stated in physical handbooks, without particular practical inferences, until Kirchhoff and Bunsen (1859) based upon them a new research, which culminated in the establishment of a law of photolytic peculiarity of chemical elements, and in the explanation of the physical causation of Fraunhofer's lines as absorptions of light from the sun's nucleus effected by the metallic vapours of the sun's gaseous envelope. Practically this research effected an immense extension of the delicacy of chemical reactions, led to the discovery of several new elements by means of that extension, and to the discovery of their general distribution in the mineral, vegetable, and animal world. I augmented the means of studying the nature of the sun, and of the fixed stars, which Fraunhofer had already shown to differ optically from the sun. The nature of heat as connected with light had first been discussed by P. Prevost (1792) on the basis of his corpuscular theory. Kirchhoff now maintained the identity of heat and light by theoremata, and showed that heat and light are forms of motion of the ether, and that heat is moved ether vibrating invisibly in longer waves than the rays which correspond to the red beginning of the spectrum.

Sun-lines.

Many sun-lines discovered by telescope.

Positive and negative spectra.

Spectral analysis of earthly and celestial objects.

Heat a part of light.

It had often been observed that various solids and fluids had particular effects upon light. Thus fluor spar assumed a particular appearance when it reflected light; the colourless solution of quinine allowed all direct rays to pass, but appeared to reflect a blue part; green chlorophyll became blood red when throwing back the sun's rays. These phenomena were long studied by Sir D. Brewster and Sir John Herschel, until Stokes established their theory, now known by the name of fluorescence. The prismatic analysis of light was found to separate heat rays, coloured rays, and a third series of rays, extending on the violet side of the spectrum, which without special precautions were invisible to the eye, but could be made visible by the effect which they possessed of transforming the atoms of certain solids and fluids into self-lighting bodies, so that these substances when placed in these rays emitted a peculiar light, differing from the colour which they bore in diffuse daylight or lamplight. Or the fluorescent bodies have the power of transforming the movements of ether, which vibrates in short waves, into long wave-vibrations. This power belongs not only to the ultra-violet, ordinarily invisible rays, but also to the violet and blue rays of the ordinary sun and gaslight spectrum. It is therefore that particular kind of light which is chemically most active by effecting combination

Fluorescence.

Chemically active rays.

and decomposition of sensitive agents which also shows the greatest influence upon bodies having the power of fluorescence.

Improved Spectrometer.

Spectrometer, improvements of.

In the cholera research I described the spectrometer which was then at my command, and the amount of accuracy obtainable therewith. Having since found the absolute necessity for greatly increasing the means of observation, I improved the spectrometer in the following way.

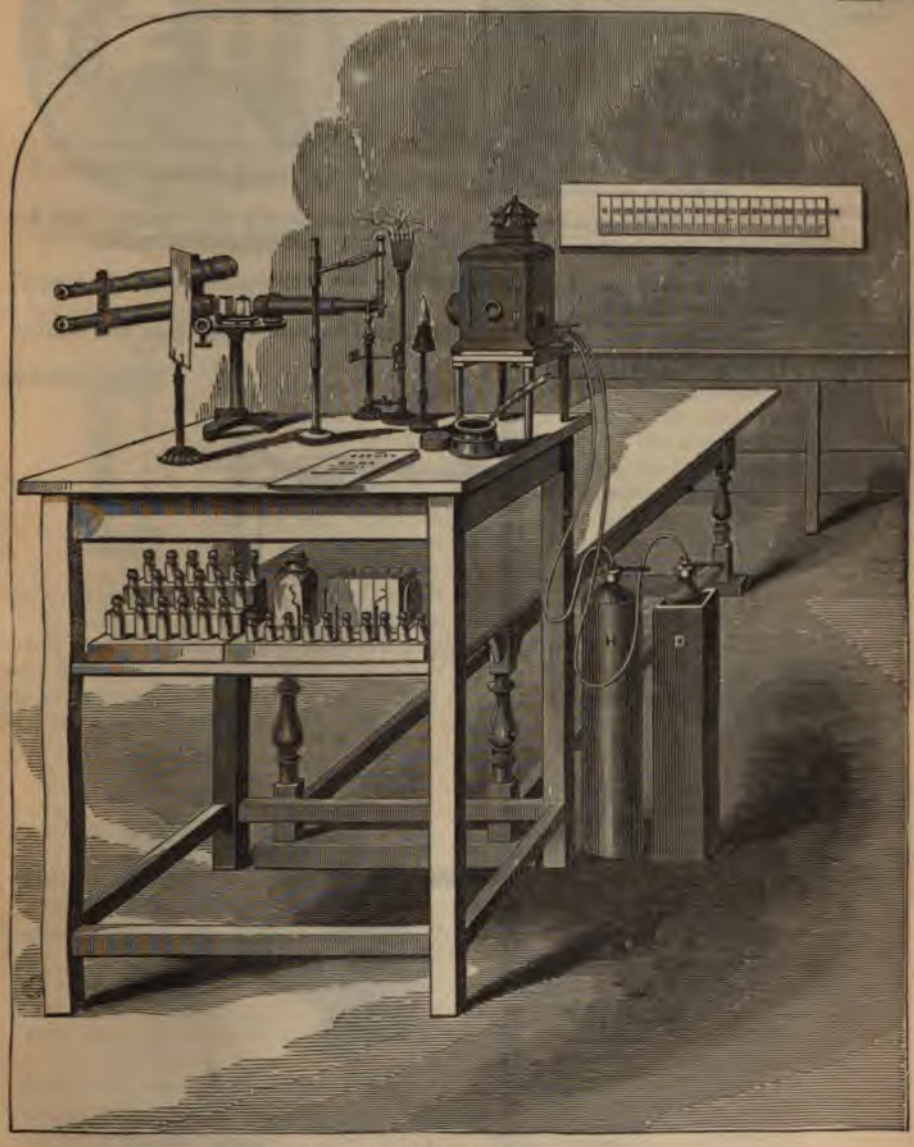
New Spectrometer.

Over the observing (astronomical) telescope I fixed a second (terrestrial) telescope of double magnifying power, the axis of which was parallel to and perpendicularly over the axis of the observing telescope. Both telescopes were provided with the usual wires across the field. At the distance of 15 feet from the observer a measure in large, bold, legible characters was put up, every point of which was observable by the adventitious telescope. By these means the scale originally observable by the nonius was increased as the distance of the new scale from the centre of the ring of the spectroscope, the effect being that while before I could read each of the 67 divisions of my entire spectrum, I could now observe and read 200; or, in other words, I increased the accuracy of my observations $4\frac{1}{2}$ fold. But by introducing a cross of spider's web into the telescope, it was possible to read tenths of each division, so that the apparatus now enables the observer to measure each of 2,000 divisions of the colour spectrum.

The accompanying engraving shows the ensemble of the arrangements

by means of which most of the following observations were made. The lantern on the right contains the arrangements for the production of Drummond's lime-light, which is supplied with oxygen and hydrogen from the reservoirs on the floor. These are iron bottles, in which the gas is contained under pressure.*

Subjoined are represented some of the details of the apparatus on the

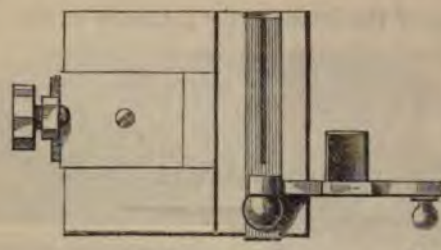


Spectroscopic Observatory.

spectroscopic table. One is the slit instrument, with arrangements for widening or narrowing the slit by means of the screw on the left. The

* This very convenient form of apparatus is made by J. Orchard, optician, Kensington.

little prism on the right can be put before the slit, in order to make a second spectrum from another source of light appear above the primary one.

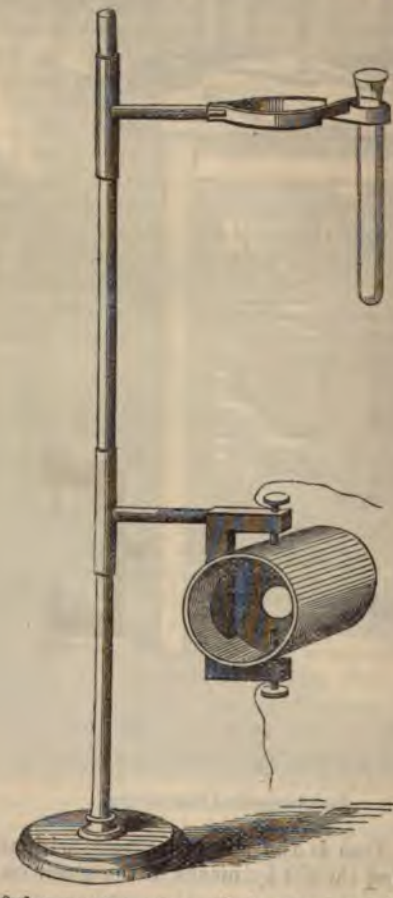


Slit Instrument.

Circular form of Slit Instrument, with the Reflecting Prism applied.

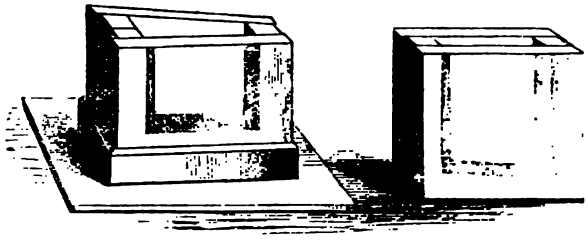
This arrangement is represented in the circular form of slit instrument here shown.

The stand with sliding holders is used for fixing test-tubes and bottles



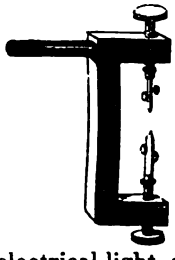
before the slit of the spectroscope. It is so arranged that for the spring clamp isolated ebonite holders can be substituted, to which the two

terminals of an electric battery and Rühmkorff coil are fastened. In the engraving the terminals are enclosed in a tube which carries a condenser. By this arrangement the eye is protected from the glare of the spark, and able to observe any fluorescence or positive spectral



Troughs of Quartz for Fluorescence Observations.

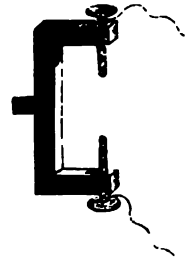
phenomena, without interference. For the fluorescence observations, little troughs of quartz, as represented in the accompanying cuts are used. When the spectra of metals are to be observed by means of the spark, two pieces of wire of the metal to be observed are clamped in the little pincettes of the isolated ebonite instrument represented in the engraving, which can be fixed to the stand above figured. The observation, by means of the spectroscope, of the spark, which passes from one wire to the other, then yields the spectra of the metals of which the respective wires are composed, superposed upon the peculiar spectrum of the electrical light, and of the gases of the air heated by the spark.



The influence of pure gases upon the spectra of the spark and of metals is ascertained by the comparison of the spectra which the spark gives in atmospheres of pure gas. For this purpose the poles are enclosed in a glass vessel, through which a current of the gas which it is desired to examine can be passed.

Influence of gases upon the electrical and metallic spectra.

Glass Vessel, Tubes, and Poles on Ebonite Isolator.



Poles on Ebonite Isolator, the Glass Vessel removed.

By the side of the stand and its isolating attachments described in the foregoing, the stand devised by Bunsen, and figured in the annexed wood-cut, is required. It carries a supply of platinum-wires fused in the

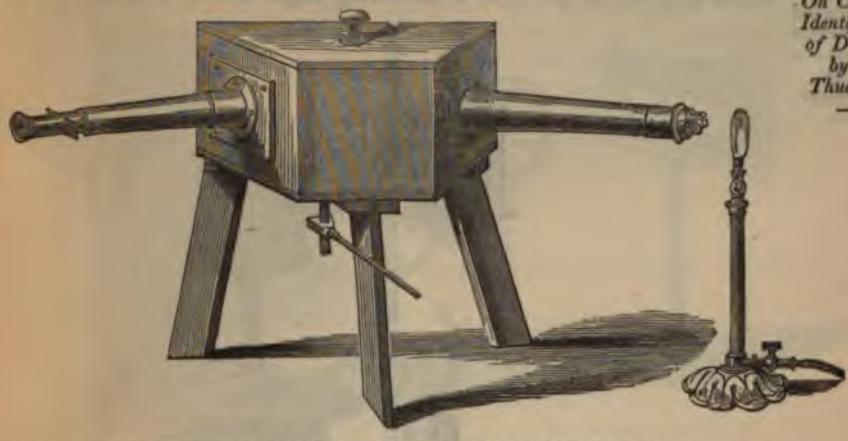
Bunsen's stand and bead-carrier.

ends of glass tubes, ready for being dipped into the matter under examination, and for being introduced into the flame of Bunsen's burner by means of the upper spring-clamped arm of the stand. The lower spring-clamp is to carry test-tubes, in which substances under examination can be heated, or, after admixture of suitable agents, be deflagrated before the slit of the spectroscope.

Bunsen's Stand, Platinum-wire Bead, and Deflagration Tube-carrier.

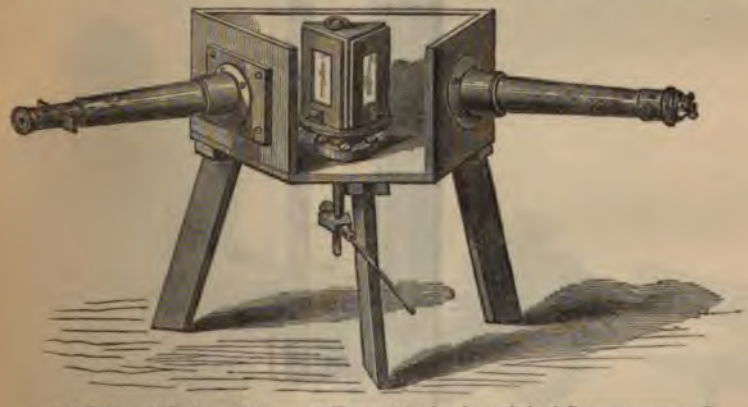
By the side of the foregoing spectroscope, I frequently had occasion to use two other spectroscopes. One was the instrument here represented. It is provided with a sulphide of carbon prism, which can be turned round its perpendicular axis by means of the turntable on which it stands, and to which the perpendicular rod and horizontal clamped lever are attached. The telescope-tube projecting on the right bears the circular slit instrument described and figured above, while the astronomical telescope on the left is provided with the sliding screens,

excogitated by Dr. A. Dupré, and represented in their actual size under the paragraph relating to the spectrum of sodium, which will be found



Spectroscope, as originally designed by Kirchhoff and Bunsen.

lower down. The internal arrangement of this spectroscope is well seen in the subjoined engraving. When in action, the two glass faces



Sulphide of Carbon Prism and Turntable, in the original Spectroscope of Kirchhoff and Bunsen.

of the prism, here turned towards the spectator, are of course turned towards the back of the box.

This spectroscope is now generally abandoned, on account of the currents produced by heat, which easily disturb the refracting medium, and make the spectra inaccurate. This error is, however, evanescent when a common gaslight is used. In my researches I found this apparatus, and the still more simple spectroscope already described in my report on cholera, invaluable. For the turning of the prism admits of the lengthening and shortening at will and before the eye of the observer of any part of the spectrum, according to the position which the prism is made to assume with relation to the incident ray of light. By these movements faint absorptions can sometimes be discovered, which would not otherwise be perceived.

The most simple form of spectroscope is the one figured herewith. It shows the entire spectrum at one glance, and of great brilliancy when a sulphide of carbon prism of a refracting angle of 60° is used. By its

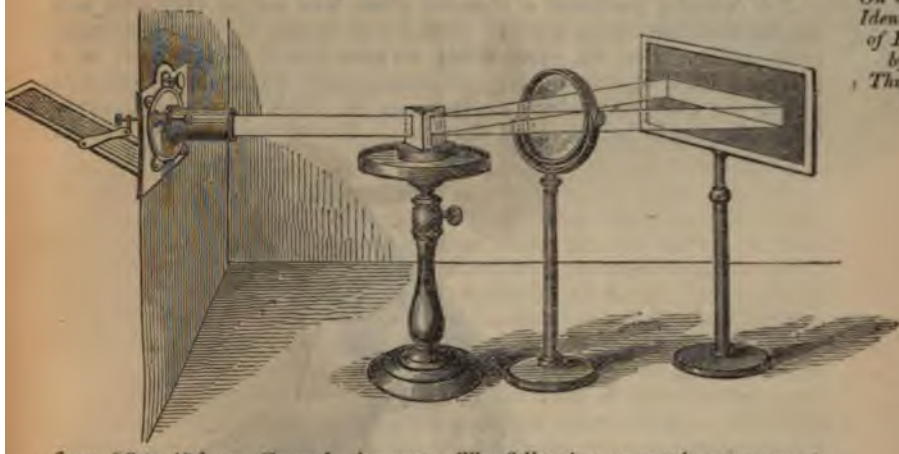
Simple non-magnifying Spectroscope and Medical Lantern, with the spirit-oxygen-lime-light.

instrumentality the fine absorption-lines of fluopittine, boviprasine, and five-banded hematine and cruentine, described in some of the following paragraphs, were discovered. It shows Fraunhofer's lines in diffuse daylight, and gives a good spectrum with any candle. In the absence of sun-light I use the medical lantern,* containing arrangements for the production of Drummond's light by means of spirit and oxygen.

The spectral phenomena, which cannot be investigated by means of the electric spark, and more particularly the phenomena of fluorescence,

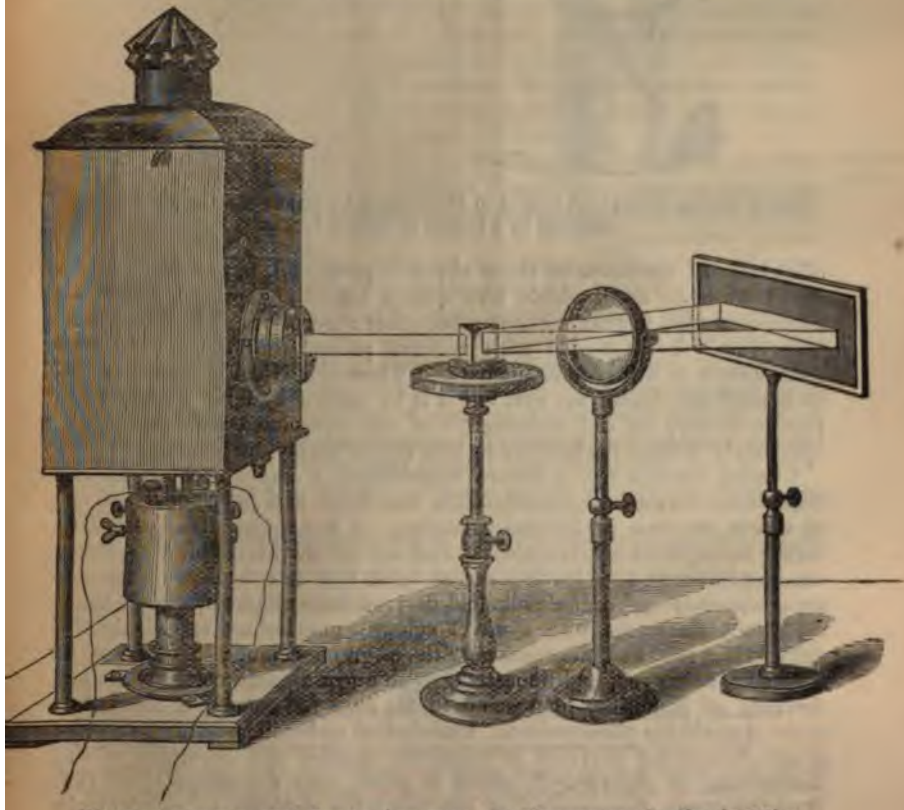
* I imagined this apparatus for the illumination of the nasal cavity, the pharynx and larynx, and other medical and surgical purposes. In respect of convenience, it is superior to any other light hitherto recommended, and in respect of power it is inferior only to reflected sun-light. It is manufactured by J. Orchard, optician, of Kensington.

have to be studied by means of sunlight, conducted into a room in the manner represented by the subjoined engraving, or an electrical lantern, supplied with quartz-lenses and prisms, and a battery power



from 30 to 40 large Grove's elements. The following engraving represents the arrangement which I use at the Pathological Laboratory, in action.

The reaction of fluorescence as a means for the identification of known substances and the discovery of new ones, is, under ordinary circumstances,



Electrical Lantern, with Quartz Apparatus, for Fluorescence Studies, in action.

best applied by means of a system of quartz lenses, which throw the light of the sun into the fluid directly without the intervention of any glass, in the manner represented in the subjoined engraving.

For ordinary purposes a common glass lens serves very well, and the intervention of the glass of windows or vessels is of no particular consequence. But for exact study all glass has to be removed, as it fluoresces itself in some degree, and consequently would absorb the rays which are able to produce fluorescence in fluids partly or entirely before they could have reached the fluids. In such examinations vessels

Mode of testing Fluids with respect to Fluoresence, by means of a Cone of Sunlight collected by a system of Quartz Lenses.

of quartz, of the shape of those above represented, but of much larger size, have to be used, which, like quartz lenses and prisms, allow the fluorescent rays to pass without perceptible absorption. The fluorescent cone should be inspected with a Nicol prism. If it be due to true fluorescence, it will remain unchanged when the Nicol is turned round its optical axis before the eye, but if it be caused by false fluorescence, that is to say, by the illumination of fine suspended particles, it will alternately become darker and lighter and of its original colour.

I must reserve for a future opportunity a fuller account of this magnificent method of investigation, the latest and fullest development of which we owe to Professor Stokes. I have used its elementary forms throughout my researches, and by its aid been able to identify many substances, and to discover at least five new bodies. Such are fluorescentine,—an organic alkaloid derived from albumen, which, being colourless, fluoresces with a violet colour; omicholine and omicholic acid, being red, and fluorescing with a green colour; a derivate of hematine, being red, and fluorescing with a grass-green colour; another derivate of hematine, fluorescing in its own red colour, a novel and most remarkable phenomenon. Omicholine and omicholic acid, and the green fluorescent derivate of hematine, exhibit the reversion of the phenomena of chlorophyll, which is green, and fluoresces blood-red. But the green fluorescence of the hematine derivate is particularly

remarkable on account of its bearing upon the so-called "dichroism" of hematine, or the property of certain of its solutions to appear green in thin, and red in thicker layers.

Application of the Spectroscope to the Discovery of Metals in Human Tissues and Fluids.

Metals occur in the human body as normal or abnormal ingredients. The normal ones are constantly present. Those which are certainly essential are potassium, sodium, calcium, magnesium, iron; those of which the presence is perhaps only accidental, though constant or at least only in substitution of sodium and potassium, are lithium, rubidium, caesium, copper, and manganese. Of abnormal ingredients we have two classes, innocuous and poisonous ones. To the former we class strontium, to the latter barium, and a series of the heavy metals, which may be medicines or poisons, or both, according to the quantity in which they are present in the body. Such metals are lead, tin, thallium, iridium, mercury, silver, antimony, arsenic, bismuth, nickel, zinc.

Metals in human body.

A considerable number of these metals may be recognized at once when a small piece of tissue is held in the flame of the colourless gas-burner, and the flame is analysed with the spectroscope. But it is preferable to first calcine the parts and fluids, after evaporation and drying in platinum vessels, lixiviate the ash with water, then with hydrochloric acid, ultimately with nitric acid, or if only ordinary metals are inquired for, with hydrochloric acid only.

The hydrochloric acid solution of the ash of the human body gives a splendid spectrum, the field of which shows many red, yellow, green, and blue lines in various parts of a dark field. By careful measurement it is found that these lines are peculiar to six metals—potassium, sodium, lithium, rubidium, caesium, and calcium. Magnesium and iron, always present in the ash, do not influence the spectrum under these circumstances. See Pl. VI. Spectr. 8, marked "Ash."

Spectrum of sodium.

The spectrum of sodium (see Pl. V. Na) is distinguished by a yellow line, which coincides with the D line of Fraunhofer. On close inspection with the magnifying glass the line is seen to consist of two lines separated by a thin black line. When much sodium is in the flame a little yellow illumination appears on both sides of the line, as an indication of a continuous spectrum. This yellow becomes intense when metallic sodium in a burning state is analysed before the slit. Then the two yellow lines fuse together with the continuous dazzling yellow spectrum, and the dark line only is seen. It is not easy to determine whether the yellow lines actually become dark, as the light has a very dazzling effect upon the eye. This reaction of sodium is the most delicate as to sodium, and the most intense amongst the reactions of the metals of the alkalies and earths. When faint lines of other bodies fall close to these yellow lines the former become invisible, as the yellow ones dazzle the eye.

To make the feeble lines visible, it is frequently necessary to exclude

the sodium line from the field of sight by a special arrangement of screens, fixed as slides in the observing telescope. (Dr. A. Dupré.)

The eye can yet recognize one $\frac{1}{3000000}$th part of a milligramme of sodium by this reaction. As two-thirds of the earth are covered with a solution of chloride of sodium, and as great masses of seawater are constantly pulverised, the sodium is everywhere. Its antiseptic properties seem a special provision against the contamination of air, earth, and water.

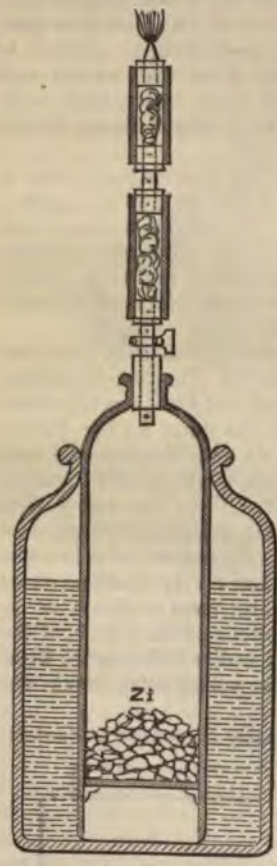
Spectrum of lithium. See Plate V. Spectrum Li.

Lithium yields as fervent vapour two lines—one Li α, red, strong; another Li β, yellow, feeble. Its reaction is very delicate, as $\frac{8}{1000000}$ths of a milligramme can yet be recognized. It is constantly present in sea water, salts, soils, animal and vegetable ashes, and is most extensively distributed over the earth. The ashes of human blood always contain a notable quantity of it.

Spectrum of potassium. See Plate V. Spectr. K.

Potassium gives a remarkable continued spectrum with two characteristic lines—one K α is red, in the ultra-red region, coinciding with the line A of the solar spectrum; another blue, K β, is in the violet end of the solar spectrum. These lines are comparatively feeble; to see them well in the magnifying spectroscope, great masses of material and great heat are necessary; it is best to use a flame of hydrogen, from a Döbereiner's apparatus.

Apparatus for hydrogen flame.



Improved Döbereiner's Apparatus for the Evolution of Hydrogen Gas.

The apparatus which I employ is made of stoneware; the inner jar fits tight into the neck of the outer, and stands upon its bottom. It carries the spelter upon a pierced movable tray. The outer jar contains the dilute sulphuric acid. As soon as the tap is opened, the acid enters the inner jar and evolves hydrogen gas; this rises, is filtered in the first cotton tube, again in the second tube containing fragments of pumice stone soaked with sulphuric acid, and is at last burned from a platinum jet, fixed in the proper place. The evolution jar must be kept sufficiently distant from all flames, so that when at the conclusion of an operation the collecting gas presses out the acid, and with it any surplus gas escapes, the mixture of air and hydrogen in the outer bottle may not be fired, but dissipated by diffusion. Orchard's compressed hydrogen can also be used.

Spectrum of caesium. See Plate V. Spectr. Cs.

The spectrum of caesium has thirteen lines, of which only three are characteristic. Cs α and Cs β are both blue, and situated midway between F and G, and Cs γ, situated between C and D. The other lines are yellow and green, and appear only when the light and heat of the burning metal are great and strong. There is always a blue continuous spectrum in the middle which makes particular screening by means of the apparatus above described necessary to see the lines one after the other. The three principal lines indicate yet $\frac{1}{20000}$ milligramme caesium.

Spectrum of rubidium. See Plate V.

Rubidium has 10 lines; of these, two red ones, Rb γ and Rb δ, are

situated on both sides of the line A, in the farthest part or end of the solar spectrum; Rb α and Rb β are violet, and situated between G and H. The other six yellow and green lines are not ordinarily visible because of the continuous spectrum which appears in the middle of the field. Of this substance $\frac{1}{5000}$ milligramme is yet necessary to exhibit the two violet lines.

Spectrum of calcium. See Plate V. Spectr. Ca.

Calcium gives a spectrum containing nine lines. Of these Ca α is rather a band of orange colour, situated on the red side of the D line Ca β is a broad green band between D and E. Between these two there are five lines which are of little use for the diagnosis of calcium, as the almost universal presence of sodium causes them to be so feeble as to become imperceptible. The eighth line is near Ca α, and towards the red end of the spectrum; the ninth line is violet, and seems to coincide with the two violet lines of rubidium, Rb α and Rb β. The reaction shows $\frac{6}{1000000}$ milligrammes calcium chloride. It is of great use in animal and pathological chemistry. Having lately to examine a pathological biliary salt, I calcined a minute quantity, and analysed the hydrochloric acid solution of the ash. Ca α and β appeared, without any other metal, even sodium was absent. This information could not have been obtained except perhaps at the sacrifice of 50 times the quantity of material actually employed. Spectroscopy therefore effects an economy of valuable materials and products which exist in quantities absolutely limited.*

Spectrum of strontium. See Plate V. Spectr. Sr.

Strontium is distinguished from calcium and barium by possessing no green lines in its spectrum. It has eight lines, six red, one orange, and one blue, of which four are diagnostic. Sr α, orange, is situated near the sodium line towards red. Sr β and Sr γ are both red, and the fourth is the blue Sr δ, which appears between F and G, close to the two blue caesium lines. $\frac{6}{1000000}$ milligr. strontium chloride give a clear reaction. Strontium has been used to investigate the possibility of the substitution of calcium by this earth in animal processes. Chicken were fed with food containing much strontia, and their egg-shells were examined. But it was found that nature could not be deceived into producing strontia shells instead of chalk shells. Only the smallest traces of strontia could be discovered in the solution of the egg-shells.

Spectrum of barium. See Plate V. Spectr. Ba.

Barium possesses the most complicated spectrum amongst alkaline earth metals. It has fifteen lines, of which two are red, one is orange, four are yellow, six green, and two greenish blue. Of these only three green lines are diagnostic. Ba α, a broad green band between E and b; Ba β, close to b, towards blue; and Ba γ, much less clear than the other two, situated between D and E, in the same place as Ca β. Between Ba α and Ba γ are three green lines, of which two have been marked Ba δ and Ba η; between b and F there are besides Ba β, two very feeble stripes of greenish blue; an orange-colored line, Ba ϵ is situated near to Sr α. Between the orange-colored and green Ba γ lines there are four yellow lines, very similar to the five yellow lines of the calcium spectrum. In the direction from the orange-red line towards the red end of the spectrum two red stripes are visible. $\frac{1}{1000}$ milligr. barium chlorate gives a good reaction. Increase of heat

* Spectroscopy is also useful in furnishing casual information. Thus the ashed end of a cigar, moistened with hydrochloric acid and held into the flame, yields the lines of sodium α, potassium α, lithium α, caesium α, rubidium α, and calcium α and β.

and quantity of material raises the brilliancy of all lines in proportion to their original intensity; but the feebly green Ba η forms an exception, which, hardly visible in a feeble spectrum, which does yet show Ba γ quite well, by intensity of heat and quantity of material becomes much more brilliant than Ba γ. In cases of poisoning by barium salts (popularly known as muriate of barytes, or barium chloride), the spectroscope is able to furnish quick information.

Peculiar bearing of Ba η.

Of other metals occurring in the human body, magnesium, iron, and manganese give no spectra in their compounds which would be useful for the recognition of small quantities. Manganese, however, can be recognized as chloride (Plate VI. Mn Cl_6) by certain light lines, which seem to recur *as absorption bands in permanganates*. Of these we will speak lower down.

Spectrum of thallium. See Plate V. Spectr. Tl.

Amongst the poisonous metals there are only two, thallium and iridium, which can be recognized by the gas flame reaction. Thallium has but one line, Tl α, which is green, sharply marked, and situated between D and E close to the latter. It is very possible that thallium may contribute to the production of the insalubrious air which prevails in some sulphuric acid factories. To the animal body it is certainly a virulent poison, and the toxicologist has to be prepared for its diagnosis.

Spectrum of iridium.

Iridium imparts a violet colour to the flame. Its spectrum has two blue lines Ir α and Ir β, of which the former is near to Cs α and towards the violet, the second about midway between Rb α and K β. The spectrum is most brilliant when the volatile chloride is used.

Spectra of other metals.

The spectra of the other metals occurring as poisons in the human body, and also those of iron, see Plate VI. Spectr. Fe, and cobalt, cannot be made to appear by means of so simple an apparatus as Bunsen's burner. They require either the heat of the electric spark produced by a strong battery and a Rühmkorff's induction coil, or the electrical arc between two carbon points of an electric lantern furnished with the power of at least 30 Grove's elements. Of these methods only the former offers opportunities for the recognition of small quantities of material; the latter requires larger quantities, and is therefore in its present shape not suitable for toxicological research. Of the heavy metals tin and mercury are best examined as gases, the former as chloride, the latter as metallic vapour. I will therefore describe their spectra with those of the permanent gases. Indium gives the spectrum pictured in In Pl. V. Plate VI. gives the spectra of didymium, erbium, copper, and silver, besides those of boracic acid, coal gas, and the electric spark.

Spectra of Simple, Permanent, and Compound Gases.

Spectra of gases.

Gases are examined by means of an electric induction spark which passes through their extremely attenuated atmosphere. The apparatus is termed after its inventor Geissler's tube, and consists of a ball and a cylinder of glass, united to each other by an extremely thin-bored thermometer tube. At each end of the tube electrodes of platinum or aluminium are inserted. The tube is filled with the gas, and then exhausted with the air pump until it has only the $\frac{1}{600}$ to $\frac{1}{700}$ part of the ordinary pressure of the air. In that state of attenuation the gas offers only a very slight resistance to the spark, which therefore passes through several feet lengths of tubing. The gas becomes very hot, and through this fervence emits brilliant and beautiful lights of various colours. The electrodes are ordinarily not volatilized, and not changed unless the gas combines with a portion of them.

Name of gas.	Colour of the light.	
	In the narrow part of the tube.	In the wide part of the tube.
Hydrogen - -	Crimson - - -	Reddish.
Nitrogen - - -	Violet red - -	Violet red, feeble.
Chlorine - - -	Green - - -	Reddish violet.
Bromine - - -	Greenish blue - -	Violet.
Iodine - - -	Green - - -	Fawn colour.
Tin-chloride - -	Golden yellow - -	Deep blue.
Silicium-chloride - -	Whitish - - -	Fawn colour.
Carbonic acid - -	Greenish white - -	Greenish white.
Hydrocarbon, $\mathfrak{C}\,H_2$ -	Rose coloured - -	Greenish.
Hydrocarbon $\mathfrak{C}\,H_4$ -	Brilliant white - -	—
Acetylene $\mathfrak{C}_2\,H_2$ -	Brilliant white - -	Brilliant white.

Diagnosis of gases by their colour.

Diagnosis of Gases by their Spectra in the incandescent State.

Diagnoses of gases by their spectra.

Oxygen can only be examined with electrodes of aluminium; platinum ones are oxydised. The spectrum, obtained by placing the Geissler's tube through which the electric spark is passing before the slit of the spectroscope, shows nine coloured lines. The most brilliant are a red and a violet one, then follow in order of strength of light two green, two blue, two greenish yellow ones, and lastly a dark red line. None coincide with any of Fraunhofer's lines.

Oxygen.

Hydrogen forms three light lines. The red line near C is the most intense; next is a greenish blue line in the place of F, and the third violet line is feeblest. Water vapour decomposes any electrodes, and gives the hydrogen spectrum.

Hydrogen.

Carbonic oxyde is obtained by the examination of carbonic acid, which is reduced. Its spectrum contains eight coloured lines, between which 10 dark lines are distributed. The most prominent are, one green, one greenish yellow, and two violet ones.

Carbonic oxyde.

Many hydrocarbons yield identical spectra when burned in the air. The inner cone of ordinary coal gas burned in Bunsen's burner, particularly the variety provided with a blowpipe tube, gives a spectrum which varies slightly with the quality of the gas. Four conical* bands are easily distinguished, of which two green ones occupy the place of $\mathfrak{Ba}\ \beta$ and $\mathfrak{Ba}\ \gamma$, the space between being illuminated by feeble green; then there is a blue band in blue, and a violet one in the violet region of the colour spectrum. There is a generic similarity of this spectrum with that of boracic acid in the gas-flame (four green bands), which inclines one to the idea that it might be due to carbon as the latter is to boron.

Hydrocarbons.

Anhydrous acetic acid, alcohol, and ether yield, the former nine, the latter two eight lines, which belong to carbonic acid (resp. oxyde) and hydrogen.

Acetic acid, Alcohol and ether.

* Conical, showing that the phenomenon is limited to a space hardly longer than the slit of the spectroscope, and more intense at its base than at its summit.

Chlorine yields six coloured and eleven dark lines. Diagnostic is a band of four yellowish green lines, a broad green line, and a treble blue line. The distribution of the coloured bands amongst the dark ones is very intricate.

Chlorine.

In chloride of tin three diagnostic chlorine lines appear, but five other lines, one yellow, another yellow double line or band cut in two by a lighter line, a green and a blue line, necessarily belong either to the tin or to the subchloride of tin, either of which may be formed in the reaction.

Chloride of tin.

Hydrochloric acid shows the lines which are peculiar to hydrogen and chlorine.

Hydrochloric acid.

Chloride of silicium shows twelve lines, three of hydrogen (impurity), three of chlorine; five or six lines only are therefore diagnostic of silicium, or silicium chloride; of these one is red, one orange, two are dark violet, and one a light green band with a lighter green line in the middle.

Chloride of silicium.

Chloride of phosphorus.

Burning phosphorus gives a continuous spectrum; its dilute vapours in a tube do not permit the spark to pass. Its chloride yields black and red stripes, three lines diagnostic of chlorine, and three lines, one orange, one orange yellow, and one violet, which are very brilliant and intensely coloured, and belong either to phosphorus or its chloride.

Bromine spectrum.

Bromine yields a spectrum with nineteen light lines, of the most varied colours, two red, one orange, eight green, four blue, and four violet. A green and a blue line are the most brilliant.

Iodine spectrum.

The spectrum of iodine contains more than twenty lines, of which four red, one orange, four yellowish green, two green, two blue, and two violet, are particularly clear.

Mercury.

Mercury in a tube so attenuated that it boils at from 40° C. to 50° C. shows nine lines, one yellow, one green, and one violet, one being distinguished by brilliancy.

Nitrogen.

The spectrum of nitrogen is very complicated, and extends from the line B to H; in the part from the red to light yellow it contains seventeen dark lines at perfectly equal distances from each other; in green there are further seven dark lines, at unequal distances from each other. At F the spectrum begins to show coloured lines and groups of lines on a dark field. Of these thirteen can be distinguished, amongst which a blue one and several violet lines are the most brilliant. The violet end of the spectrum extends very far, and can be made beautifully visible by fluorescent substances. These substances show that hydrogen possesses no such fluorescent spectrum. When the slit of the spectroscope is made wider, the groups of lines of the nitrogen spectrum fuse to continuous bands of greater width without any dark intervals. This illustrates a frequent occurrence, namely, that broad bands, by narrowing of the slit, are resolved into bands of the width of the slit. The spectrum of air contains the lines of nitrogen and oxygen.

Practical application of the above spectra.

It must be left to the future to decide how far these spectra can be practically utilized in the diagnosis of gases which occur in the animal economy. Such gases as occur in morbid emphysemata (in the cellular tissue of cows during cattle plague, in contused limbs with effused blood) in the blood in various conditions, in certain internal cavities or tissues as results of diseases, have hitherto mostly escaped analysis, as their small quantity makes the ordinary methods inapplicable. The attention of inquirers must henceforth be directed upon their analysis by means of the electro-spectroscopical method.

Application of the Spectroscope to the Diagnosis of Coloured Gases, Fluids, and Solids, by means of the Phenomena of Absorption.

When coloured translucent bodies are placed in the path of the ray of sun or lamp light before it enters the prism, they frequently effect a change in the appearance of the spectrum. Certain parts are extinguished, others altered in colour, and these effects are found to be specific to bodies of definite chemical composition. The gases of iodine, bromine, and nitrous acid exhibit a great number of hair-fine lines, similar to the lines shown by the solar spectrum itself, but of different theoretical value. The lines of nitrous acid increase in number by heat, and decrease by cooling. The vapour of indigo on the other hand possesses no lines, all the more singular as its solution has a particular line or band in its spectrum. Such changes in the spectrum indicate that these bodies so alter the motion of a certain part of the light that it is unable to produce an effect upon the retina of the eye; the change is termed absorption. Amongst the solid bodies the coloured glasses are the most powerful in the production of these phenomena. The red varieties, termed ruby-glasses, which owe their tint to suboxyde of copper, are the most homogeneous. They only allow red and a small part of orange to appear in the spectrum; all other colours are more or less absorbed. The orange-coloured glasses containing iron oxyde, the light yellow ones containing silver chloride, the smoke-yellow ones containing antimoniate of potassium or soot, and the green glasses containing oxyde of copper or chromium, allow the greater part of the spectrum to F and G to pass. But most blue glasses show particular obscuration in the shape of bands. As these are frequently used as spectacles and windows in eye-infirmaries, and are known to be coloured by cobalt, it is necessary to consider the influence of this metal. Some sodium diborate moistened with a solution of cobalt-chloride was fused to an eye of platinum wire, and the pellucid blue pearl while soft pressed between platinum plates; it showed three bands in the spectrum.

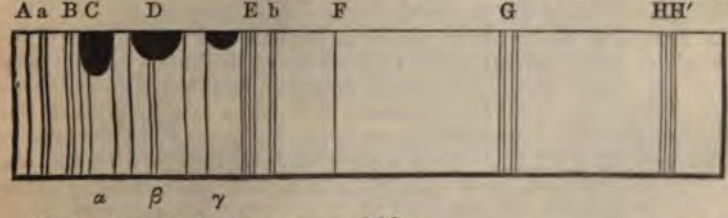
Definition of absorption.

Coloured glasses.

Cobalt-glass.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	= 142° 25′ — 142° 6′	= 0° 19′	3	α
2 in yellow to green	= 141° 55′ — 141° 24′	= 0° 31′	2	β
3 in green not clear.	= 141° 12′ — 140° 53′ (approximatively).	= 0° 19′	1	γ

Intensity Diagram of the Spectrum of Sodium Diborate Cobalt-glass.



No further shades in green and blue.

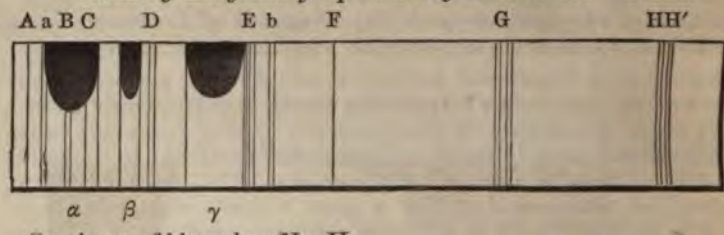
The spectrum of a beautiful blue glass (I.) from Messrs. Powell & Son's factory in Whitefriars gave

Blue glass No. 1.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	= 142° 43′ — 142° 12′	= 0° 30′	5	α
2 red and orange	= 142° 0′ — 141° 48′	= 0° 12	4	β
3 in green	= 141° 24′ — 140° 51′	= 0° 33′	4	γ

No shades in green and blue.

Intensity Diagram of Spectrum of Blue Glass. No. I.



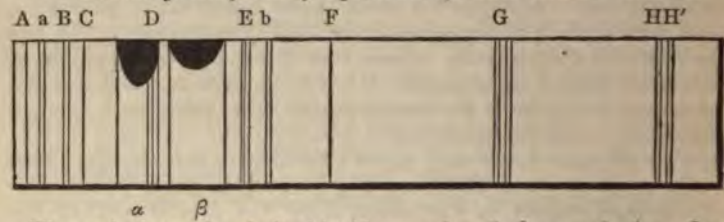
Blue glass. No. II.

Specimen of blue glass No. II.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	= 142° 0′ — 141° 36′	= 0° 24	3	α
2 in green	= 141° 30′ — 141° 0′	= 0° 30	2	β

No further shades in green and blue.

Intensity Diagram of Spectrum of Blue Glass. No. II.



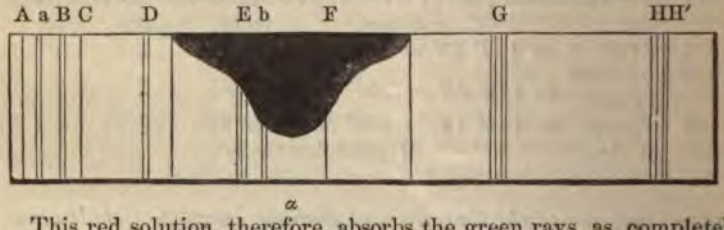
Solution of cobalt chloride.

The solution of cobalt-chloride employed for producing the blue bead above described had a pink colour, no absorption in red, yellow less vivid, and a broad band beginning with green and reaching to blue.

$$\alpha = 141° 30' - 139° 12' = 2° 18'.$$

The blue was then continued to the end.

Intensity Diagram of Spectrum of Solution of Cobalt Chloride.



This red solution, therefore, absorbs the green rays as completely as the blue glass absorbs the green of plants.

The foregoing observations can be multiplied and varied upon different kinds of glass, several layers of progressive thickness, and thereby undergo great variation. All effects, however, result in a great abbreviation of the red part of the spectrum, in a pallor or absorption of the yellow, in an obstruction and absorption of the green, and perhaps a prolongation of the blue. Such glass therefore excludes from the eye a great mass of colours, or of such light as has the most exciting effect upon the retina.

Manganese glass.

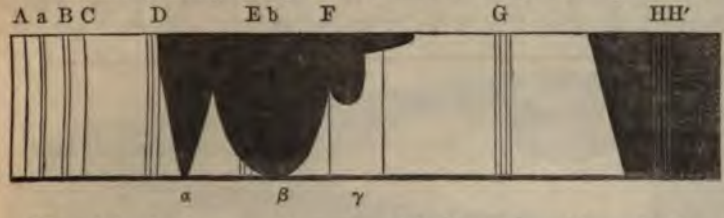
Some violet glasses, coloured with oxyde of manganese, show a darkness about D, and another in dark green and beginning of blue. We observe phenomena reminding of these in solution of permanganate of potassium. A very dilute solution is dark rose-pink, and shows an absorption band from yellow to blue, and some further shading.

Solution of permanganate.

Measurement.	Width.
141° 36′ — 140°	= 1° 36′ for black band.
140° — 139° 30′	= 0° 30′ for shading.

The first part of band seems to be a narrow band, α, a small interval of feeblest light succeeding ; then a broad band, β, then a narrow feebler band, γ, seems to follow ; ultimately the shading nearest to blue.

Intensity Diagram of Potassium Permanganate Spectrum.



The violet is absent. Compare with these absorptions the four positive bands of manganic chloride.

Of crystals, those of didymium salts offer the most interesting phenomena of absorption (see diagram in Cholera Report, p. 493), as they are the direct reversion of the spectrum of the fervent didymium flame. Erbium offers similar appearances, through the reverse of its absorption spectrum is not produced by its vapour, but appears by the simple glowing of a bead of its earth.

Didymium crystals.

Erbium.

The Effects of Fluids upon the Spectrum.

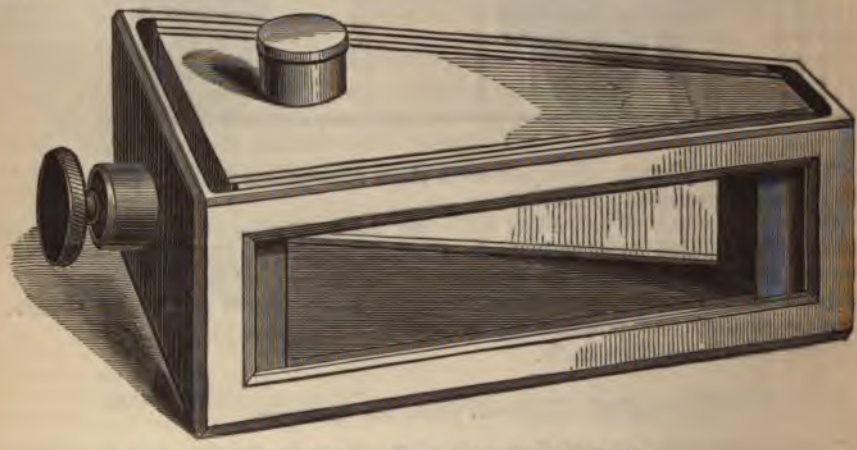
Effects of fluids upon the spectrum.

These are absorption and fluorescence phenomena. As they may be useful hereafter for the ready diagnosis of poisons and medicines, and for other purposes of forensic medicine, I have subjected many of them to examination. The principal application of spectrology will, however, be to the chemistry of the normal and pathological ingredients of the body. While, therefore, I shall state of general researches only the shortest results, I shall devote a special chapter to the elucidation of the spectral phenomena of the blood, its physiological and pathological changes, particularly those effected by poisonous gases and fluids, and to the changes effected in the spectral phenomena of blood by chemical agents, or the spectrology of hematine and many of its derivates. The latter will afford me an opportunity for proposing a new method for the discovery of blood in medico-legal cases under particularly difficult circumstances, where hitherto all other proceedings have failed.

Hollow Prism of Gutta Percha, glass and brass.

Many of these solutions were examined in test tubes, or bottles of larger diameter. Others were placed into hollow prisms which I had made for the

purpose. Such a prism consists of a wedge-shaped cell of gutta percha, open on both its long sides and lined with india rubber; two pieces of plate-glass are strongly pressed upon these sides by means of the brass frame and screw at the end. When closed the apparatus can be filled and emptied by the aperture on the top, shown in the engraving as closed by the gutta percha stopper. It is never taken to pieces except for thorough cleaning. In such a prism one and the same fluid can thus



Larger hollow Prism for more dilute Fluids.

be examined in layers varying from half a centimetre to three centimetres in thickness. Two prisms can be used placed in opposite directions for studying the complementary effects of different solutions, *e.g.*, of sulphocyanide of iron and prussian blue in oxalic acid. Among the apparently monochromatic fluids the yellow-coloured ones mostly allow the entire spectrum to pass. The pure yellow tinctures of sabadilla, datura, belladonna root, colchicum, colocynth, nux vomica, and cantharides offer no particular features in the spectrum. Those which like certain kinds of olive oil show absorption, owe this quality to an admixture of impurity. Of red and blue solutions, those of sulphocyanide of iron, of prussian blue, and of the ammoniacal solution of copper-oxyde, permit a considerable part of the spectrum to pass. Sulphocyanide, however, when coupled with a layer of prussian blue, extinguishes the entire spectrum.

Prolongation of red part of spectrum.

Some solutions prolong the red part of the spectrum in the direction of the heat spectrum. This peculiarity belongs to a particular variety of pure yellow olive oil, and to the essential oil of the Bergamo lemon peel; also to certain kinds, not all varieties, of tincture of rhubarb, after dilution with spirit of wine. These fluids also exhibit a black absorption band in red; in the less pure and very impure olive oil two more feeble absorption bands in green appear. All these absorptions are probably due to the admixture of xanthophylline. Animal fats, including human, have never yet been found to possess absorptive qualities, although they are frequently very powerfully fluorescent. It is curious that some, not all varieties of the tincture of rhubarb, orange peel, and of compounds made with their aid, show bands in red of variable breadth, which have some similarity to the band produced by hematine in alkaline alcoholic solution, and to the first band in red of acid hematine solutions; but the differences are clearly and easily evolved by careful manipulation, to be described below.

Bands from impurity.

Of poisonous tinctures, that of aconite yields a spectrum coinciding by its bands with that of xanthophylline produced from chlorophyll. (Valentin; Simmler.) The tinctures of hemlock and foxglove yield two xanthophylline bands, of which the second is rather a narrow line than a band. The tincture of hyoscyamus shows only a band in red, and the rest of the spectrum clear.

Tincture of aconite and other vegetable poisons.

Many alkaloids yield peculiar colour-tests with various agents, such as sulphuric acid and potassium diochromate, manganese, nitric acid, and others. Not one of these, whether possessing poisonous, medical, or indifferent properties, yields by such reaction coloured fluids which show any particular spectral phenomena or absorption bands. (Valentin.)

Colour-tests of alkaloids yield no bands.

Many coloured fluids of organic and inorganic origin show one or more narrow or broad bands in the yellow, green, or blue part of the spectrum. Such are chloride of chromium, the solution of cobalt, permanganate, indigo, and others. Of all these I shall attempt a systematic arrangement in a future elaboration.

Various fluids give bands in yellow to blue.

Some solutions which have little colour of themselves, such as iron chloride and copper nitrate, sulphate, and acetate, absorb (like the oxalic acid solution of prussian blue already mentioned) the red part of the spectrum. These latter blue solutions are therefore frequently used in investigations concerning the fluorescence of substances.

Solutions which absorb red end.

The potassic solution of oxalate of chromium-oxyde, even in so dilute a state that the eye hardly perceives any coloration, absorbs the yellow rays in the neighbourhood of D. Thicker layers or more concentrated solutions absorb the rest of the yellow, the orange and the green rays next to yellow. Very concentrated solutions allow the red rays only to pass, and then a dark line of Fraunhofer's can be seen, which is ordinarily visible with the best prisms only. (Brewster.) Oxalic acid mixed with red chromate of potassium gives a dark violet fluid, which allows red to pass, absorbs all light from C to half-way between C and F, and then green to a little beyond F. The dry residue of this fluid, which forms into scales, gives a similar spectrum. (Valentin.) I have examined the green fluids which chromate and sulphuric acid give with matters which are oxydized with the mixture, *e.g.*, alcohol, and found them to yield particular absorptions. The permanganate spectrum has already been mentioned, as also the phenomena exhibited by didymium compounds. Those of uranium also show absorption bands. (Brewster and Gladstone.)

Peculiar effect of potassic solution of chromic oxyde.

Green solutions of chromate, sulphuric acid, and alcohol.

Amongst the coloured substances occurring in nature, or produced by art, which are used for dyeing, none appear to possess the properties of simple colours, inasmuch as all permit more or less of different colours to pass. If any possessed only one colour, it would allow only that colour to pass, and would give a spectrum showing complete darkness everywhere except in one particular place, where a coloured band of the width of the slit of the spectroscope would appear. Nevertheless many of these matters have peculiar effects upon the spectrum, by which they can be distinguished, however similar they may appear to each other in ordinary daylight. Some of the solutions, when examined in certain concentrations, allow no light at all to pass; others allow red to pass even through very thick layers; others, like picric acid, allow red, orange, yellow, and green to pass. Their phenomena on progressing dilution are also noteworthy. Frequently the blue and violet part become visible first, and the absorption remains only in the yellow and green part. Picric acid, however, absorbs the violet in even very dilute solutions, and prussian blue in oxalic acid the red. Most substances have a limit of dilution, which, when transgressed, produces a complete disappearance of all absorptions. This limit can only be ascertained if

Dyes.

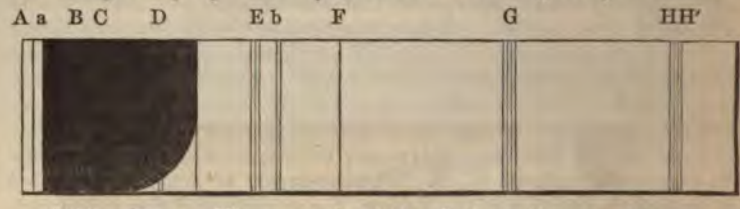
Limits of dilution.

Aniline dyes.

strength of solution and thickness of layer interposed are carefully noted. Some bodies bear from five to ten-fold the dilution of others before their absorptions disappear. This relative power of absorption, as governed by quantity, temperature, solvent, should always be borne in mind in any development which it may be intended to give to the spectral method. In the following description reference is mostly to solutions of medium concentration, which allow the absorption bands, or other principal phenomena, to appear best.

Aniline Dyes.—The concentrated solution of roseine allows red from A to C to pass, and absorbs the rest of the spectrum. A solution of 1 in 10,000 shows an absorption reaching from D to half-way between F and G. On progressive dilution the band becomes narrower, until in a solution of 1 in 100,000 it assumes its narrowest limits; these it retains until it disappears at a dilution of 1 in 600,000.

Diagram of Spectrum of Aniline Ponceau (green) in alcohol.



Aniline Blue.—The concentrated solution allows red to pass; 1 in 5,000 shows a broad band between C and E, which on dilution becomes narrower, and remains with the D line for its middle. At 1 in 8,000 it reaches its narrowest limits, and on progressive dilution it becomes gradually feebler and disappears at 1 in 20,000.

Nicholson blue has the same spectra as magenta, to be described immediately.

Aniline Violet is very similar to the foregoing spectra, but its absorption band is situated intermediately between those of the other two. It disappears on dilution to 1 in 60,000. A mixture of roseine and aniline blue shows a similar bearing.

Diagram of Spectrum of Aniline Violet, or "Magenta."

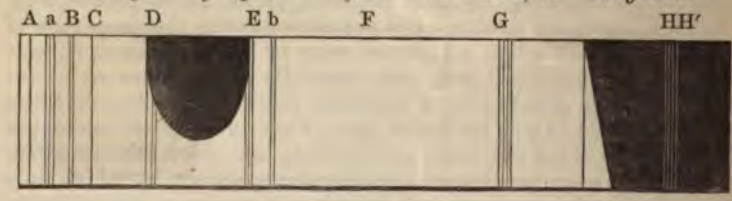
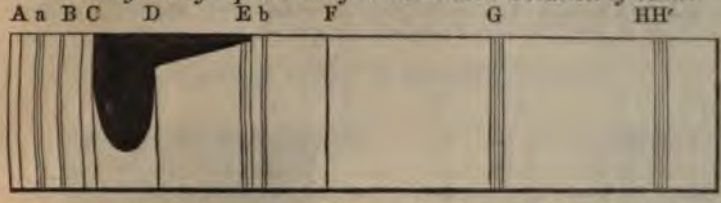


Diagram of Spectrum of Concentrated Solution of Humbold's Violet in Water.

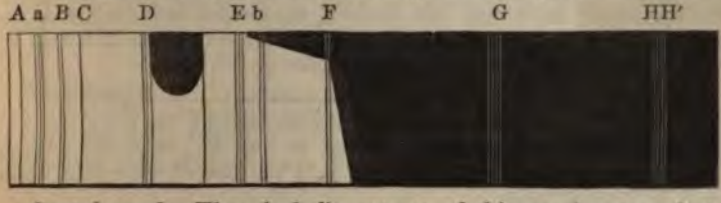
Diagram of Spectrum of more diluted Solution of same.



Logwood. *Logwood.*—A decoction of logwood, when sufficiently concentrated, allows red light only to pass. Diluted with from 7 to 8 parts of water blue from F to G appears. Diluted with from 18 to 20 parts of water, the absorption band is at its minimum width; it disappears when the original decoction is diluted with 24 parts of water.

Brazil-wood. *Brazil-wood.*—A decoction of this wood allows red and orange to pass; 16 times diluted blue and violet appear; a band remains between D and E, and disappears on dilution of the original solution with 45 times its bulk of water.

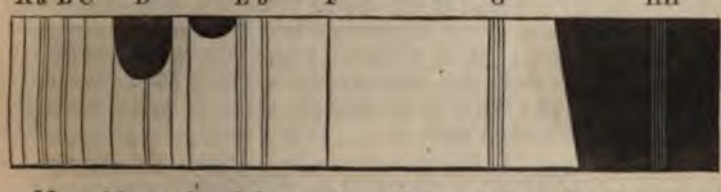
Diagram of Spectrum of Watery Solution of Brazil Wood.



Santal-wood. *Santal-wood.*—The alcoholic extract of this wood passes first red, then orange rays; diluted 35 times yellow and green to E appears; blue is seen when the dilution is 55, and a band appears from E to beyond F. At 60 dilution this band separates into two narrow ones, of which one situated between E and C disappears only at a dilution of 200, while the other, situated near F on the side towards G, becomes invisible somewhat earlier.

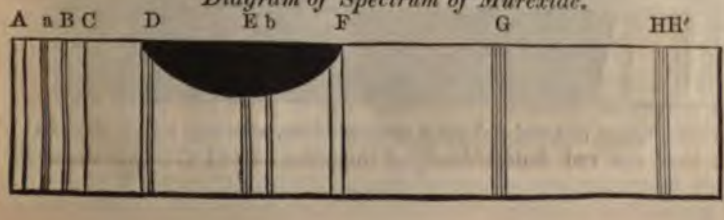
Cudbear. *Cudbear* shows red and yellow, and then retains two absorption bands on the violet side of D, which remain to the 23rd dilution.

Diagram of Spectrum of Watery Decoction of Cudbear.



Murexide. *Murexide*, produced from uric acid by nitric acid and ammonia, is similar to some violet aniline dyes, but is distinguished by its spectrum, which is as follows:

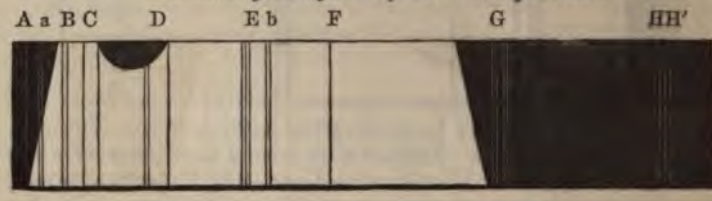
Diagram of Spectrum of Murexide.



Litmus.

The blue tincture of *Litmus*, obtained by digesting the little magnesite cakes, exhibits a band in yellow 142° 12′ — 141° 30′ = 0° 42′. Spectrum cut off at 138° 48′; red slightly shortened.

Intensity Diagram of Litmus Spectrum.



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Reddened by hydrochloric acid the tincture shows no band; the blue becomes feeble; all is turbid; again made blue by caustic potash the former band reappears, and the rest of the spectrum becomes again very bright.

Indigo.

The similar spectrum of indigo and its sulpho-compounds I have described in the cholera report.

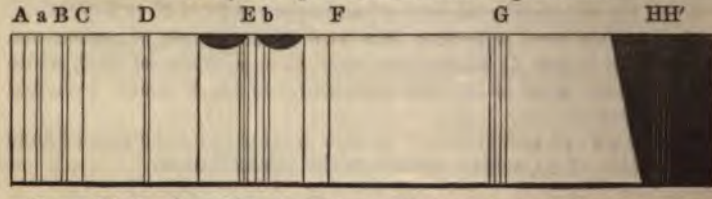
Cochineal alizarine.

Cochineal, the crimson matter from the cochineal insect, and alizarine, a colouring matter extracted from madder, are similar to santal-wood in this that they show two bands each. The powdered cochineal boiled in water on appropriate dilution shows two bands,

	Measurement.	Width.
1 in green	= 141° 12′ — 140° 48′	= 0° 24′
2 in green to blue	= 140° 42′ — 140° 12′	= 0° 30′.

Blue continued to the end. Intensity of both bands when first seen separate = 1.

Diagram of Carminic Acid Spectrum.



Some kinds of cochineal yield so-called neutral solutions, the spectrum of which shows only one band at any degree of dilution to disappearance. By alkali the absorptive power of carminic acid is much increased, and the two bands appear, even in dilutions containing much less of the acid. Ammoniacal solutions are quickly oxydised and lose their absorption bands. The bands of alizarine are situated more towards the blue than those of carminic acid.

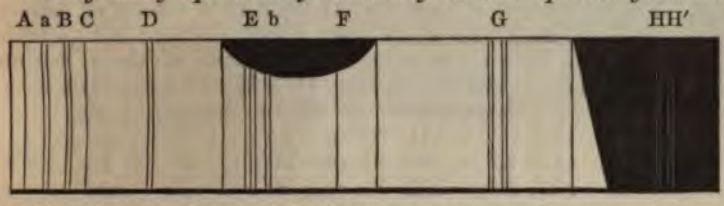
Diagram of Spectrum of Alizarine.

On comparing the red-coloring matter of some other lower animals, I found that the red fluid (blood) of the common earthworm contains

hematocrystalline, the same as is contained in the blood corpuscles of the vertebrata. It is, however, not attached to corpuscles in the earthworm, but dissolved.

Blood of earthworm contains hemato-crystalline.

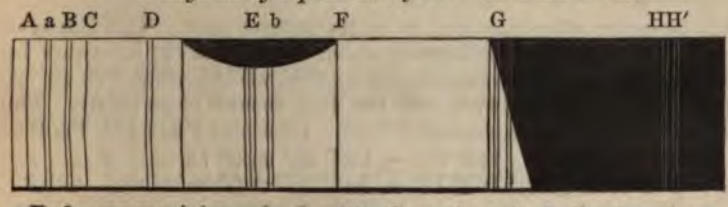
Diagram of Spectrum of Extract of Chromatophores of Lobster.



The chromatophores of the lobster contain a red matter of the colour of blood. On microscopic examination this is seen to be contained in spiderlike cells. It is insoluble in water, a little soluble in alcohol, more soluble in acetic acid and alcohol. The solution is yellowish red. Spectrum: red and yellow, complete; in green at 141° a shading begins, which passes into a kind of violet (not black), and ends with the beginning of blue at 139° 30′ width of band = 1° 30′. The end of the violet is at 137° 36′. A layer of fluid of double the thickness cut off the spectrum at 141° 18′. (See Plate III. fig. 6.)

Chromatophores of lobster.

Diagram of Spectrum of Red Currant Juice.



Red currant juice mixed with three times its bulk of water gave a red fluid, the spectrum of which showed apparent similarity to that of the lobster chromatophores. Red, yellow, then dark at 141° 24′ to 140° 12′ = 1° 12′. Blue to the end. (See Plate III. fig. 7.)

Red currant juice.

Apart from the chemical differences of these solutions, the spectral ones are eminently diagnostic. Passing over the width of the bands we perceive in the nature of the obscuration a difference, the band in the currant juice is simply dark, that in the chromatophores solution has a fluorescent tinge.

Of yellow dyes picric acid is a good type. The saturated alcoholic solution in a layer of one centimetre in thickness allows red, yellow, and green to near F to pass; diluted with two alcohol it extends to F; on gradual dilution the spectrum extend slowly until at dilution 150 blue to G appears, at dilution 400 G is cleared, and at 700 the colour extends to near H. The entire spectrum is only lighted up at dilution 2,500.

Yellow dyes. Picric acid.

The tincture of turmeric, when saturated, has a reddish yellow colour. In layers of one centimetre thick it allows colours from red to half green 140° 48′ to pass. It shows a beautiful green fluorescence in the cone of sunlight condensed by a system of quartz lenses.

Turmeric.

Many yellow dyes show similar phenomena, amongst them camboge, yellow wood, French berries, purrée, annotto, sumach, and bark or quercitron.

The knowledge concerning these bodies can only attain its full development by studies upon pure immediate chemical principles, instituted with the most expansive spectrometric methods, and absolute regard to the phenomena of fluorescence.

Various yellow dyes.

In these respects the vegetable world seems to offer an almost endless field of study. Its phenomena here and there obtruded themselves upon

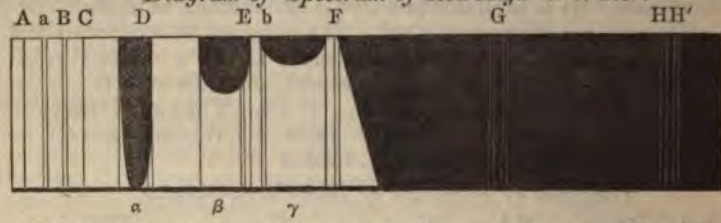
Red algæ on human bone.

my attention without my seeking. Thus a human thigh bone which was macerating in the conservators apartment of St. Thomas's Hospital was brought to me for examination. It was covered with a red gelatinous mass. The glass vessel in which it was steeped in water was similarly covered. The microscope showed the red material to consist of minute cells in a gelatinous mass, with which green larger cells were interspersed. The water filtered from them contained a number of these minute bodies in suspension ; it was red, and gave the following spectrum :—

Band.	Measurements.	Widths.	Intensity.	Rank.
1.	142° 0′ — 141° 36′	= 0°24′	7	α
2.	141° 12′ — 140° 46′	= 0°26′	2	β
3.	140° 39′ — 170° 0′	= 0°39′	1	γ

Spectrum cut off at 139° 54′.

Diagram of Spectrum of Red Algæ in Water.



This spectrum presents a matter in its natural state. The following spectrum will exhibit the difference which was effected in its nature by alcohol and boiling. The mass appeared fluid while boiling, but on the filter it completely gelatinised, and the fluid ceased to percolate. The filtrate, which was green, remained fluid. (See also Plate III. fig. 8.)

1 in red	142° 37′ — 142° 25′ = 0° 12′	5	α
2 in or to green	142° 12′ — 141° 36′ = 0° 36′	1	β
3 in green, shaded at	141° 18′ limits uncertain	1	γ

Diagram of Green Alcohol Extract of Red Algæ.

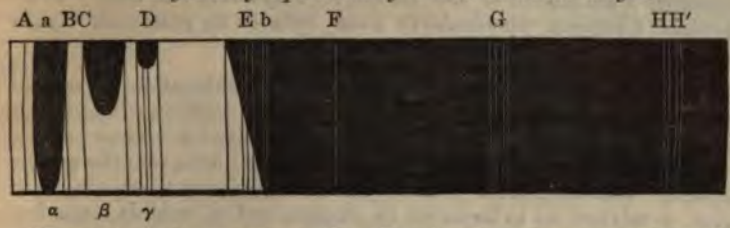
Green algæ in pond at St. Thomas's Hospital.

Green Matter from Cellular Algæ in the Pond of St. Thomas's Hospital Gardens.—These matters are of some interest, as their origin (summer 1866) was by uninformed persons ascribed to the proximity and operations of the Pathological Laboratory, which is situated upon the bank of the pond. The algæ were minute single cells with granular contents, many of the corpuscles being green. Filtered from the water and dried, a light green mass appeared, firmly adhering to the paper. This adhesion was owing to the gelatinous colourless material in which the cells were imbedded. The paper yielded nearly all its green colouring matter up to alcohol. The solution was green, fluoresced red in sunlight, and gave a blood-red cone with a lens. It had, therefore, the essential properties of chlorophyll ; of its spectrum the red was shaded.

1 in red	142° 48′ — 142° 30′ = 0° 18′	10	α
2 red to yellow	142° 18′ — 142° = 0° 18′	5	β
3 or to green	141° 54′ — 141° 36′ = 0° 18′	2	γ

Green shading quickly at 141° 12′, cut off at 141°. (See Plate III. fig. 9.)

Diagram of Spectrum of Green Cellular Algæ.



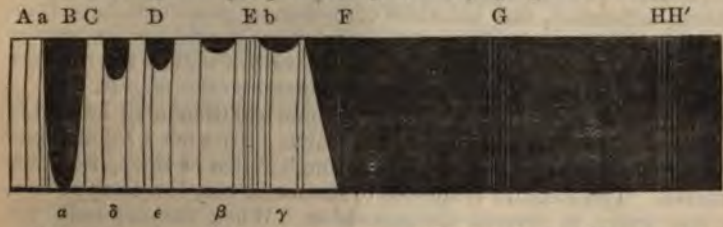
The rest of the spectrum though colourless shows a curious feeble illumination. Having disposed of this objection to the Pathological Laboratory, I compared the chlorophyll from grass. This was all the more interesting as Berzelius had mentioned his belief that chlorophyll and the green colouring matter of bile, biliverdine, were identical. Grass was extracted with caustic potash, and the solution precipitated by hydrochloric acid. The green precipitate was extracted by alcohol. It had stood more than a year when spectroscopically examined.

Chlorophyll from grass.

Bands.	Measurements.	Width.	Intensity.	Rank.
1 in red	142° 48′ — 142° 18′	= 0° 30′	10	α
2 red to orange	142° 12′ — 141° 54′	= 0° 18′	2	δ
3 orange to green	141° 42′ — 141° 24′	= 0° 18′	1	ϵ
4 in green	141° 12′ — 140° 54′	= 0° 18′	8	β
5 in green to blue	140° 42′ — 140° 18′	= 0 24′	5	γ

Last term difficult to read. Blue cut off; feeble illumination of colourless end. The solution fluoresces red in solarlight pencil. (See Plate III. fig. 10.)

Diagram of Spectrum of Chlorophyll from Grass.



This substance is therefore quite different from the one extracted from the algæ, and corresponds to the description first given of the green colouring matter of plants by Sir D. Brewster. Several chemists deny that this spectrum belongs to a simple body, and the comparison of the spectrum of the green algæ seems to confirm that opinion. For its three bands are so similar to the first three bands of the extract from grass, that they may well be considered to be identical. One of the bands certainly exists in the green leaves of some plants, but the presence of all has not yet been proved. Sunlight or electric or Drummond's light must be employed for their investigation. The five-band spectrum is interesting on account of a certain similarity to the spectrum of some forms of cruentine, of which more below. Some colouring matters derived from bile, to be described below, yield spectra, which have bands not dissimilar to the three-band chlorophyll from algæ. But true biliverdine in alcohol shows no bands; one half of its spectrum is of a brilliant red, without any yellow, the other half is of a splendid green. In sunlight it shows no fluorescence.

2.—*Spectral Phenomena of the Blood, its Physiological, and Pathological Changes, particularly those effected by poisonous Gases and Fluids; its Changes by chemical Agents.*

The spectral phenomena of the blood are a combination of optical effects produced partly by chemical, partly by mechanical agencies. The mechanical ingredients act rather as impediments to clear perception or complete perception of all appearances, and have therefore to be eliminated. But even after that the chemical ingredients remain in so complex a mixture as to be liable to change, and to exhibit imperfect spectra. Perfect spectra can only be obtained upon chemically pure matters, and when these are once established as standards, the more obscure and imperfect spectra can be referred to, compared, or identified with them. I shall show further on that acid hematine, when prepared pure, shows four or five absorption bands, while only three are seen upon less pure solutions, and only one when these less pure solutions are not viewed in sunlight or oxy-hydrogen light, but in the ordinary gas-light or lamp-light of laboratories. For these and other reasons I prepared a number of specimens of hematocrystalline and hematine, and their derivates, in various ways, and subjected the products to spectropopy.

Beating the blood.

Mode of separating Blood-corpuscles from Fibrine and Serum.—As the corpuscles become entangled in the coagulating fibrine, the blood has to be beaten or stirred with a broom of decorticated birch or whalebone. The mixture of serum with red and white blood-corpuscles can, in the present state of science, not be separated into its constituents so as to leave the corpuscles pure and unchanged. Chemical means have therefore to be employed, by which this separation may be effected with a minimum of change.

Separating the blood-corpuscles.

Solution of salts.

There are solutions of salts of a certain degree of concentration. Sulphates, carbonates, and chlorides of sodium or potassium have been employed. The concentration of these solutions should not be greater than is required to effect the object. Of chloride of sodium the smallest quantity seems necessary, of carbonate of potassium the largest.

NaCl solution.

One volume of saturated chloride of sodium solution may be mixed with from 9 to 19 volumes of distilled water. To such a solution one volume of blood, beaten and filtered through calico or linen, is added, and stirred. The mixture is allowed to stand at a very low temperature, in ice and water, to prevent decomposition. When the corpuscles are deposited the supernatant liquid is decanted, and the sediment is again stirred with the same quantity of the chloride of sodium solution as before. This is repeated a third and fourth time.

Decanting and filtering.

The decanted liquid is by no means clear, but contains many blood corpuscles in suspension. It is very difficult to filter it, but I have to some extent succeeded in filtering it through calico extended almost horizontally over a frame. It is necessary to filter in warmer weather because the mixture cannot be left at rest for longer than three days, even in cold weather, and during that time only few descriptions of blood deposit the greater part of their corpuscles. Every three days the salt water has therefore to be renewed, and the completion of this washing process therefore takes from nine to twelve days.

Washing.

Varying time required by the corpuscles of different animals to deposit.

The blood corpuscles obtainable from the slaughter-house, from oxen, sheep, and hogs, are very imperfectly deposited, and with them washing can hardly be effected more than three times. The blood corpuscles of men, dogs, cats, guinea-pigs, and rats are deposited much sooner. Those from birds and amphibia settle the quickest.

Peculiarity of *horse* blood.

The blood corpuscles of the horse show a peculiarity in this, that they

sink quickly in their own serum, and can therefore be separated from it a first time without addition of salt water. But they deposit very slowly in salt water, and therefore offer no advantage over oxen and sheep's blood.

Mode of extracting Hematocrystalline.—When the blood corpuscles thus freed from serum are shaken with ether and water, the red-coloured ingredient dissolves in the water; and if this solution, after rapid filtration, be exposed to a low temperature, crystallises at once, if it came from dogs, rats, guinea-pigs, or squirrels; but if it came from birds crystallises only after addition of one quarter of its volume of alcohol of 80 °/₀, and exposure to a cold of from — 5° to 10° C. The crystals obtained are separated by filtration, washed with dilute alcohol (1 part of 80 °/₀ in 4 water), pressed between blotting paper, redissolved in a minimum of water, filtered again, mixed with ¼ volume of alcohol, and exposed to the low temperature. By this proceeding not crystals but an amorphous deposit of hematocrystalline is obtained from human blood and the blood of cattle collected in slaughter-houses. To such blood a modified process is best applied as follows:—The corpuscles are isolated by means of soda-sulphate or common salt, and then shaken with water and ether. After separation of the ether the red water-solution is treated with a solution of basic lead acetate as long as a precipitate ensues. This is removed by filtration; the excess of lead by a little potassium carbonate. To the filtrate powdered potassium carbonate is given until the hematocrystalline separates in grumous flakes. These are separated by filtration and strongly pressed. The cake is again broken and mixed with a little watery alcohol, which causes the separation of potassium carbonate in solution. Again strained and pressed the cake may be dissolved in water, and precipitated by alcohol, or by alcohol and cold.

Mode of extracting and purifying hematocrystalline.

Mode of obtaining amorphous cruorine.

Chemical Composition.—According to the analyses of C. Schmidt and H. Seyler, the crystals from dogs, guinea-pigs, and geese have the following composition:—

Chemical composition of blood-crystals.

	Dogs.		Guinea-pigs.		Geese.
C	53·64	-	53·85	-	54·26
H	7·11	-	7·32	-	7·10
N	16·19	-	16·17	-	16·21
S	0·66	-	0·39	-	0·54
Fe	0·43	-	0·43	-	0·43
O	21·02	-	21·84	-	20·69
P_2O_5	0·91	-	—	-	0·77
Alkalies	0·04	-	—	-	—
	100·00	-	100·00	-	100·00

From these data the formula $C_{600}\ H_{960}\ N_{154}\ Fe\ S_3\ O_{177}$ has been calculated, leading to an atomic weight of 13280, far surpassing in magnitude that of any other molecule hitherto dreamed of in organic chemistry. While we may be quite certain that the atomic weight is very near that figure, we cannot determine it absolutely as yet for the following reason: the blood crystals retain more or less oxygen in loose combination like the blood itself, and yield it up in the vacuum, provided they are moist, but retain it the more tenaceously the dryer they are. We can determine the oxygen given off but we cannot as yet say whether any and how much oxygen is yet contained in the crystals in this particular form. Calculating from the quantity of iron contained in them as unit, we arrive at 13023 as the molecular weight.

Formula and molecular weight.

Hematocrystalline combines readily and more pertinaciously than with oxygen with a number of other gases, such as carbonic oxyde, nitric oxyde, and hydrocyanic acid. It is peculiarly decomposed by sulphuretted and phosphuretted hydrogen, the latter agent producing a complete disappearance of all particular spectral phenomena. The study of its changes, which with so high an atomic weight, are probably extremely numerous, is therefore of paramount importance in pathological chemistry, and that the more so, as the muscles are also pervaded by hematocrystalline, and any change touching it in the blood may influence equally the whole or any part of the muscular system.

Spectral phenomena of hematocrystalline.

Spectral Phenomena of Hematocrystalline.—When a concentrated solution of hematocrystalline is placed before the slit of the spectroscope, and sun-light or lime-light employed for illumination, only some of the extremest red light is perceived in the spectrum. On continued dilution with water the illumination extends towards the D line, but before the region of this line has appeared clear, light is perceived in the green between the lines C and F. On continued dilution the extension of the light proceeds more towards F, and the dark region in the middle of the spectrum, which may now be called a band, contracts but slowly. But it ultimately allows light to pass over its middle, and is soon seen to consist of two bands. Of these the narrower, darker, and stronger defined one is situated towards the red close upon the D line, while the second wider, but paler one, is by the side of E. From this point the solution may be greatly diluted with the effect only of producing some shrinking in the width of the bands. But ultimately they become very pale, and when the solution has ceased to show any colour to the naked eye the bands also have completely disappeared. That these absorptions are properties of the blood circulating in the living body can be shown by experiment. Place the ear of a man or of a rabbit, or the closed commissure of the fingers, before the somewhat widely opened slit of the spectroscope in strong sun-light, and the bands will immediately appear. All red-coloured blood, in which the colour attaches to corpuscles as in vertebrata, or to the fluid as in the common earth-worm or the house-fly, yields these bands, and they are evidence that the matter imparting this red colour is identical in all, and is hematocrystalline. The spectrum can be seen upon thin sections of blood-clot, of muscle, or the thinnest layer of blood fixed upon glass in the manner in which microscopists are wont to preserve blood corpuscles. It can be seen upon the light reflected from a surface of blood, or upon single blood crystals, or by means of a spectroscope fixed to the eyepiece of an ordinary microscope, upon a single blood corpuscle.

Hematocrystalline does not easily putrefy.

The hematocrystalline is the last ingredient of blood which undergoes putrefaction ; it preserves its colour and spectrum for years in a horribly offensive mixture, to which air has only moderate access. The putrefying blood evolves nitrogen and carbonic acid, and that with such tension that in one of my experiments it burst a bottle with explosive violence, by a collected pressure which could not have been less than 15 atmospheres. This kind of decomposition reminds of that which I found in cholera-stools, and described in the last report of the Medical Officer. The stability of hematocrystalline is the main factor in the stability of life. This quality is perhaps mainly the result of the power which it possesses of taking up oxygen from the air and yielding it again to other matter in contact.

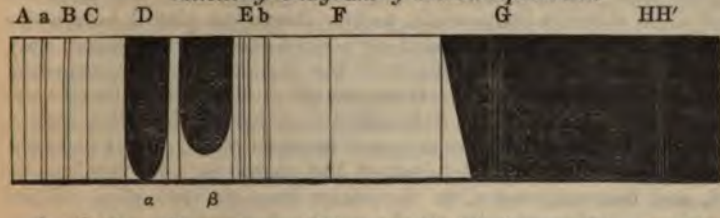
The spectrum of blood, or hematocrystalline, is represented in fig. 1 of plate I. Measured repeatedly on my first spectrometer it shows :—

Spectrometric data.

Band.	Measurements.	Width.	Intensity.	Rank.
1. Yellow to green	141° 54′ — 141° 30′	= 0° 24′	10	α
2. In green	141° 24′ — 140° 54′	= 0° 30′	8	β

There is green, feeble blue, cut off at 138° 54′.

*Intensity Diagram of Blood Spectrum.**



A solution of hematocrystalline containing 2 per cent., examined in a layer of one centimetre in thickness, allows only the red part of the spectrum to penetrate. A solution of $\frac{1}{2}$ per cent. permits some green light to pass, diluted to $\frac{1}{4}$ per cent. it admits of the distinction of the two bands. A solution of 1 in 1,000 shows both bands already narrower ; they become still narrower on dilution, and disappear at a dilution surpassing 1 hematocrystalline in 10,000 water. From this it is evident that the delicacy of the spectroscopic test for blood is very great, and it has indeed been estimated, that if 5 cubic centimetres of water contain 0·00005 grammes of hematocrystalline, and are so arranged in a thin tube before the spectroscope that the light has to penetrate a thickness of the solution equal to 10 centimetres, they will yet yield the spectrum and give evidence of the presence of blood. This quantity is equal to 0·00775 grains, or say nearly $\frac{8}{1000}$ of a grain of hematocrystalline.

Quantitative determination of delicacy of spectrum as test.

* With the spectrum of the blood may be compared that of the blood-red feathers of the wings of the Cape Lory (*Turacus albocrystatus*), and of that of the alkaline

Diagram of Spectrum of Feather of Cape Lory.

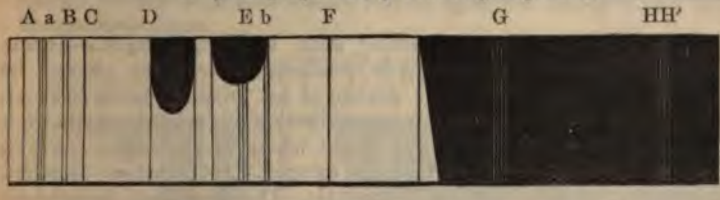
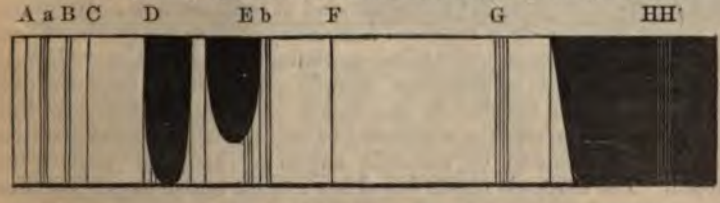


Diagram of Spectrum of Alkaline Solution of Pigment of the same.

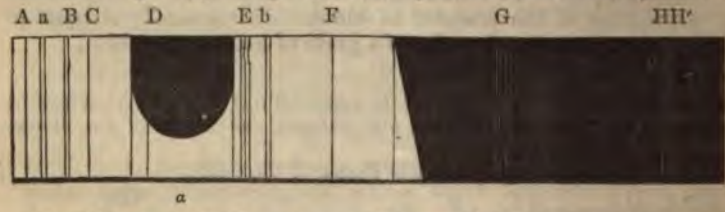


solution of their pigment, of which the general similarity to the spectrum of oxyhematocrystalline is still greater (see Plate IV. figs. 9 and 10). This spectrum was discovered by Prof. Church, who found the pigment to contain copper.

Reduced hematocrystalline.

Reduced or Deoxydised Hematocrystalline.—The body described in the foregoing paragraph is the oxydised hematocrystalline, or arterial blood-colouring matter. By substances which attract oxygen this is easily changed, as was first shown by Stokes, into reduced hematocrystalline. Such reducing substances are serum, or serum diluted with water; hydrogen, and arseniuretted hydrogen; a solution of iron suboxyde sulphate in ammoniacal tartrate. When through a solution of blood in water which shows both bands well hydrogen with arseniuretted hydrogen is passed, and the fluid is allowed to be at rest a little while, and is thereupon placed before the spectroscope without being agitated or poured into another vessel, only one broad band is seen in place of the former two. It measures $141° 48' - 140° 48' = 1° 0'$, spectrum cut off at $139° 23'$ is therefore of the same width as, or perhaps $0° 6'$ wider than that of the two oxydised blood bands, including the green space between them, but is moved a little more towards the violet end of the spectrum. Its intensity is only 8, and decreases more on the violet than the red side. When the solution is shaken up with air the one band disappears, and the two oxydised hematocrystalline bands reappear. The solution of iron suboxyde in ammoniacal tartrate is also very certain and handy, but it always yields a turbid spectrum, not to be compared in definition with the one obtained by the foregoing process. After oxydation by air the solution treated with iron has to be filtered to show the two blood bands again. It becomes quite black and impenetrable to light under certain circumstances. The spectrum of reduced hematocrystalline or venous blood is represented in plate I. fig. 2. Its intensity diagram is here subjoined.

Intensity Diagram of Spectrum of reduced Hematocrystalline.



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Combination of hematocrystalline with carbonic oxyde.

Combination of Hematocrystalline with Carbonic Oxyde.—It has long been known that carbonic oxyde produces a particular change in the colour of blood, which is not destroyed by mixture with oxygen. It was shown that this was due to a combination of carbonic oxyde with hematocrystalline, which is always found when these bodies come in contact. The carbonic oxyde displaces oxygen, and remains attached to the hematocrystalline even in its crystals. The compound has almost the same spectrum as oxydised hematocrystalline, but the bands are situated a little more towards the violet end of the spectrum. By none of the means which reduce oxydised hematocrystalline can the bands of the carbonic oxyde hematocrystalline spectrum be changed or reduced. Upon the fixity of this combination, therefore, depends the fatal effect of carbonic oxyde when inhaled for any length of time. Further by the fixity of its spectrum can the compound be recognized, and consequently poisoning or suffocation by carbonic oxyde or charcoal vapour be diagnosed. The carbonic oxyde blood has a more bluish tinge than the venous or arterial.

Hematocrystalline and nitric oxyde.

Combination of Hematocrystalline with Nitric Oxyde.—Nitric oxyde, when passed into a solution of blood previously treated with hydrogen

or ammonia, expels oxygen as well as carbonic oxyde from their combination with hematocrystalline and combines with it. The absorption bands remain in the same places, although they are a little paler. The blood loses its power of being affected by reducing agents; but reduced solutions are made light red again by the nitric oxyde. The compound of hematocrystalline and nitric oxyde crystallises in the same forms as those with oxygen and carbonic oxyde.

Hematocrystalline and hydrocyanic acid.

Combination of Hematocrystalline with Hydrocyanic Acid.—This combination is obtained crystallised by addition of hydrocyanic acid to hematocrystalline solutions under the circumstances above related. It loses acid by recrystallisation. The compound is less stable than the two compounds just mentioned. By addition of deoxydising agents to the solution the spectrum of reduced blood is obtained. The spectrum of the combination shows no differences from the ordinary blood spectrum. It is of course natural to seek the poisoning action of hydrocyanic acid in its affinity for hematocrystalline. Experiments show, however, that this must be otherwise. For the blood corpuscles in cases of poisoning by this agent do not retain any of the acid, as they do when it is brought in contact with them directly. It must be abstracted from them again somewhere in the body. Hydrocyanic acid is the only acid which does not decompose hematocrystalline. All other acids immediately effect a cleavage into albuminous matter and hematine.

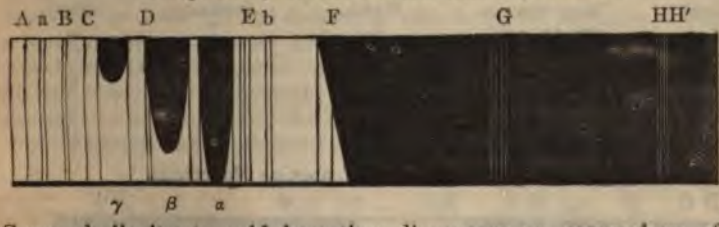
Influence of hydrothion upon blood.

Influence of Sulphuretted Hydrogen or Hydrothion upon Hematocrystalline.—Little hydrothion has no visible influence upon the spectrum. It passes through the circulation when injected into the rectum, and is exhaled unchanged by the lungs. But a concentrated solution or long-continued action changes the hematocrystalline completely. The blood bands disappear and three new bands appear instead, which have the following positions, intensities, and ranks :—

Band.	Measurement.	Width.	Intensity.	Rank.
1.	142° 12′ — 141° 55′ =	0° 19′	3	γ
2.	141° 42′ — 141° 18′ =	0° 24′	8	β
3.	141° 12′ — 140° 54′ =	0° 18′	10	α

The interval between 1 and 2 is remarkably yellow, even in a turbid solution which has stood for 24 hours. There is as yet no treatment known by which this substance can be again transformed into oxydised hematocrystalline.

Diagram of Blood treated with Hydrothion.



Some similarity to acid hematine disappears on comparison of the measurements. The peculiarity of the spectrum is very evident from its representation in fig. 7 of plate I. But it was found by Stokes that by reducing agents this body yielded the spectrum of reduced hematine. It may therefore be a solution of hematine in a peculiar acid, the nature of which remains to be investigated.

Blood treated with alcohol and ammonia.

Blood treated with Alcohol and Ammonia.—Blood was mixed with twice its volume of alcohol, and the coagulum filtered from the liquid. The latter showed no spectrum-bands. The coagulum dissolved in

ammonia showed a spectrum with three bands, which had a general resemblance to the sulphuretted hydrogen blood-spectrum, but showed very different measurements.

Band.	Measurement.	Width.	Intensity.	Rank.
1.	142° 18′ — 141° 54′ = 0° 24′	3		γ
2.	141° 42′ — 141° 24′ = 0° 18′	7		β
3.	141° 18′ — 140° 36′ = 0° 42′	7		α

Diagram of this Spectrum, represented in Fig. 8 *of plate* 1.

When this solution was mixed with alkaline iron protoxyde sulphate a spectrum of two bands appeared, which measured—

1. 141° 30′ — 141° 12′ = 0° 18′ int. 10. α
2. 141° — 140° 42′ = 0° 18′ „ 3. β

Blue end cut off at 140°.

This was therefore the reduced hematine spectrum, of which we shall find the details lower down.

Spectral phenomena of hematine.

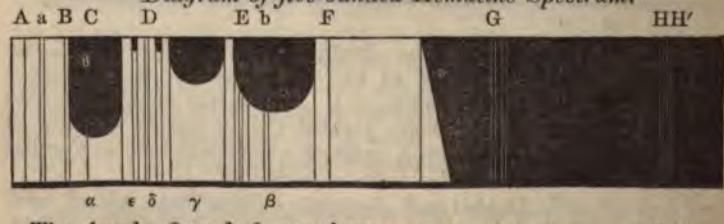
Spectral Phenomena of Hematine.—When hematocrystalline is treated with acids or alkalies and alcohol, it is split up into albuminous substances and a coloured matter, which retains all the iron, but none of the sulphur of the original compound. This is hematine. It appears from my researches that there are at least three different kinds of hematine recognizable by the spectroscope, besides a number of combinations which may be formed by one or perhaps all of them.

Five-banded hematine.

Five-banded Hematine.—Blood corpuscles isolated from serum by sulphate of soda in the manner above described are treated at the ordinary temperature with alcohol, to which a little sulphuric acid has been added. This solution was found by me to possess five absorption bands, three of them being those of acid hematine, first described by Stokes, two others being situated in red and orange, and narrow, one very fine, like a narrow bundle of sun-lines.

Band.	Measurement.	Width.	Intensity.	Rank.
1.	46 to 56	10	7	α
2.	58 to 60	2	1	ε
3.	64 to 70	6	1	δ
4.	79 to 96	17	3	γ
5.	98 to 117	19	5	β

Diagram of five-banded Hematine Spectrum.



The bands 2 and 3 are best seen in the non-magnifying spectroscope with a sulphide of carbon prism, and a good gaslight. The

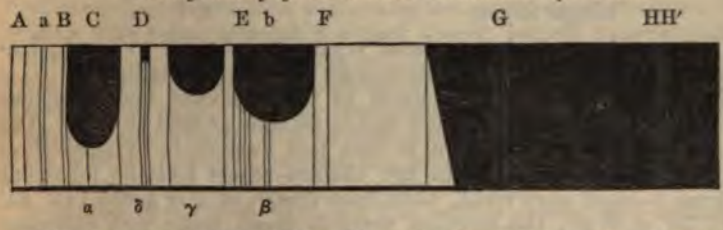
magnifying spectroscope with flint-glass prisms shows them less distinctly.

Four-banded Hematine by a modified Process.—When the corpuscles are boiled in water after treatment with sodium sulphate, so that all sulphate is removed, and are then treated with acidified alcohol, a solution is obtained which gives a spectrum similar to the former by its three lines, 1, 4, and 5, or α, β, and γ, but instead of ε and ζ there is only one line midway between the places occupied by the two. This is identical with the spectrum of hematine first described by Stokes. It was also obtained by dissolving pure crystallised hematine in alcohol and little sulphuric acid by the aid of a gentle heat.

Band.	Measurement.	Width.	Intensity.	Rank.
1.	41 to 55	14	7	α
2.	61 to 64	3	1	δ
3.	74 to 93	19	3	γ
4.	96 to 120	24	5	β

End of blue at 157. The interval between the band 3 and 4 is very obscure. Band 2 in Drummond's light became in thick solution rather stronger, measuring 63 to 72=9.

Diagram of four-banded Hematine Spectrum.



Acid hematine in water.

Blood treated with Acid.—The simple addition of acid to blood changes its spectrum. When an organic acid, such as acetic or tartaric, is taken, one band in red appears, and great obscuration of the rest of the spectrum ensues. The one band in red belongs to acid hematine, and the darkness in green is due to two other bands. These, first correctly described by Stokes, it is not easy to define without the aid of sunlight or Drummond's light. They have therefore not been noticed by later authors. Upon the purest specimens of acid hematine they can, however, be observed and measured with tolerable accuracy. The acid solutions of hematine were hitherto believed to contain a particular body, which was termed hemine. It is, however, quite easy to show that it is hematine, for its spectrum can by alternate acidification and alkalification be made to yield the bands either of acid or alkaline hematine. The following measurements were observed upon tartrate of hematine :—

Band.	Measurements.	Width.	Intensity.	Rank.
1 in red	142° 30′ — 142°	= 0° 30′	8	α
2 in green	141° 30′ — 140° 58′	= 0° 32′	3	β
3 do. to blue	140° 54′ — 140° 6′	= 0° 48′	5	γ

Alkaline hematine.

Alkaline Hematine.—In order to fully study the phenomena of hematine I produced a quantity of it in a neutral state. A large quantity of amorphous hematocrystalline was made from 10 gallons of blood and a hundredweight of potassium carbonate. The isolated material was dried at 40° C, and extracted with cold absolute alcohol. The splendid ruby red solution was treated with a solution of tartaric acid in absolute alcohol as long as a precipitate fell down. The filtered

Pure crystallised hematine.

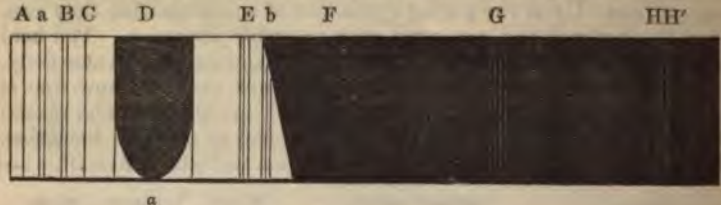
solution was then slowly evaporated at 40° C., until it deposited all colouring matter as a fine powder of black, somewhat violet, colour. This was filtered off, the powder washed with alcohol, lastly with water. It was then redissolved in absolute alcohol and potassium carbonate. Tartaric acid was again added, and crystallisation completed as before. Ultimately a black violet powder remained, consisting under high powers of the microscope of little rhombic scales, mostly crossed and imitating well the shape of the hemine crystals. I believe this to be pure crystallised hematine. It certainly contained no hydrochloric acid, and negatived the assumption hitherto made by some animal chemists, that all crystallised hematine was identical with hemine, and like hemine was a hydrochlorate of hematine. I reserve communication of the chemical analyses of this substance for future opportunities, and confine myself to the spectral phenomena offered by this matter. For I have shown above that what different authors term hematine are different substances. It is thereby explained why each new inquirer should have found results differing from those of his predecessors. Thus the iron in hematine was ascertained to be, by

Mulder	-	-	-	6·7 per cent.
Le Canu	-	-	-	7· ,,
Rollet	-	-	-	7·2 ,,
F. Simon	-	-	-	8·2 ,,
Hoppe Seyler	-	-	-	8·9 ,,

The latter author, who had declared crystallised hemine to be a hydrochlorate, has just retracted his statements regarding hematine.

The neutral hematine is insoluble in water, alcohol, and ether, but dissolves in caustic alkaline water and in alkaline or acid alcohol. The spectrum of the acid solution is that just described. The alkaline alcoholic solution described in my cholera report had the following spectrum :—Red very vivid, band from orange to near green 142° 24′ —141° 36′ = 0° 48′, the terminal towards green being with difficulty determined on account of the green being very much shaded. The spectrum cut off entirely at C; when diluted it measured 142 °18′ — 141° 42′ = 0° 36′ or 142° 18′—141° 48′ = 0° 30′, but the pure hematine in alkaline alcoholic solution now produced shows a somewhat different spectrum. Band 142° 0′ — 141° 16′ = 0° 44′. Intensity 8 = α.

Diagram of pure alkaline Hematine Spectrum.



The band is therefore broader and in a different position from that formerly described. The causes of this difference remain to be investigated. Treated with a little sulphuric acid the spectrum immediately becomes that of acid hematine. β very indistinct but dark, γ with a decided red tinge. The margin on the blue side most difficult to read, but there is a decided blue interval between it and the final darkness.

Band.	Measurements.	Width.	Rank.
1.	142° 18′ — 141° 54′ =	0° 24′	α
2.	141° 12′ — 140° 48′ =	0° 24′	β
3.	140° 42′ — 139° 54′ =	0° 48′	γ

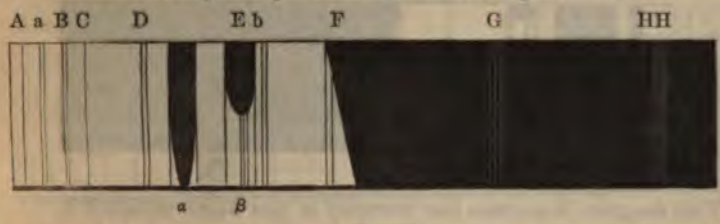
Reduced Hematine.—When an alkaline watery solution of hematine is mixed with a deoxydising agent such as the alkaline tartrate solution of ammonio-sulphate of iron suboxyde, the former spectrum gives way to a new one, showing two bands. See fig. 6, plate I.

Band.	Measurements.	Width.	Intensity.	Rank.
1.	141° 30′ — 141° 12′	= 0° 18′	10	α
2.	141° — 140° 42′	0° 18′	3	β

Blue cut off at 140°.

Reduced hematine.

Diagram of reduced Hematine Spectrum.



This body was first produced and its spectrum observed by Stokes, "The two bands are situated at about the same distance apart as those "of oxy-hematocrystalline, and are no less sharp and distinctive. They "are a little more refrangible, a clear though narrow interval interve-"ning between the first of them and the line D. They differ much from "the bands of oxy-hematocrystalline in the relative strength of the first "and second band. With oxy-hematocrystalline the second band appears "almost as soon as the first, on increasing the strength or thickness of "the solution from zero onward, and when both bands are well developed "the second band is decidedly broader than the first. With reduced "hematine on the other hand, the first band is already black and intense "by the time the second begins to appear. Then both bands increase, "the first retaining its superiority until the two are on the point of "merging into one by the absorption of the intervening bright band "when the two appear about equal. Like hematocrystalline reduced, "hematine is oxydised by shaking up its solution with air."

Cruentine, a derivate of hematine.

Cruentine, a new derivate of Hematocrystalline and of Hematine.—When human or animal hematocrystalline is boiled with sulphuric acid it becomes chemolysed, the albumen dissolves and yields its particular products, a portion of the hematine also dissolves and colours the fluid ruby red, while a brownish red grumous matter remains suspended in the fluid in an insoluble state. This is a mixture of neutral cruentine with its sulphate. By washing with water this matter loses sulphuric acid, and becomes ultimately free from it. Treated with sulphuric acid it dissolves completely, and is now sulphate of cruentine.

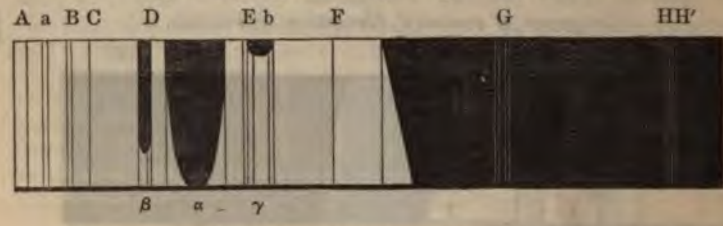
Cruentine sulphate.

Cruentine Sulphate.—When a concentrated solution of this body is examined with the spectroscope it shows one broad black band, in red to orange 142°—140° 30′=1° 30′, blue cut off at 139° 36′. The visible blue is about as extensive as the visible green. On dilution this band splits up into two, and a third very feeble band in green becomes visible just to disappear. We have thus a spectrum of three bands.

Bands.	Measurements.	Width.	Intensity.	Rank.
1 in yell. & orange	142° — 141° 50′	— 0° 10′	8	β
2 green	141° 30′ — 141° 8′	— 0° 22′	10	α
3 green	140° 48′ — 140° 30′	— 0° 18′	2	γ

The order of intensity of these bands is not the same in all dilutions. There is a point when γ is just visible, intensity 1, at which α and β are of equal intensity, while just before the dilution at which γ appears the first band, 1, is decidedly most intense. On continued dilution, however, the first band disappears before the second. The absorption is at all times equal to that of blood, so that when the fluid shows the merest tinge of pink the bands are yet clearly visible.

Diagram of Spectrum of Sulphate of Cruentine.



This diagram illustrates the intensity of the bands of figure 9, plate I.

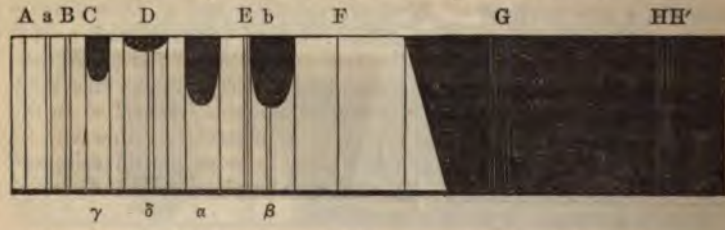
Neutral fluorescent cruentine.

Neutral fluorescent Cruentine.—When the insoluble residue from the sulphuric acid treatment is washed to neutrality and dried, a portion of it is soluble in ether and chloroform. The ether solution has four bands, which are a little paler than, but as nearly as can be identical with, the bands of the chloroform solution. This latter prepared by boiling is dark red, and shows spectrum—

Bands.	Measurements.		Width.	Intensity.	Rank.
1.	142° 18′ — 142° 3′	=	0° 15′	3	γ
2.	141° 55′ — 141° 30′	=	0° 25′	1	δ
3.	141° 21′ — 141°	=	0° 21′	5	α
4.	140° 45′ — 145° 18′	=	0° 27′	5	β

Blue dark, cut off at 139° 9′.

Diagram of Spectrum of neutral fluorescent Cruentine.



The saturated chloroform solution was one Ctr. thick. The spectrum was measured with the aid of a gaslight only. It fluoresced with a splendid blood-red colour in the sun-cone. This is the first body which is known to fluoresce with homogeneous light, that is to say, the same kind of light or colours which it transmits. The fluorescent cone has an intensity of colour equal to that of a solution about ten times more concentrated. Considering its beauty alone the phenomenon may be placed by the side of those exhibited by quinine, chlorophyll, or cud-bear. But by its peculiarity it is perfectly unique.

Alkaline Four-banded Cruentine.—Spectrum 11, plate II., represents

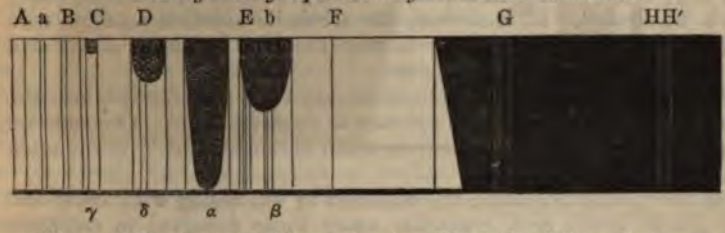
solution in alcohol of cruentine made alkaline by ammonia. It measured—

Alkaline four-banded cruentine.

Bands.	Measurements.	Width.	Intensity.	Rank.
1.	142° 15′ — 142° 6′ =	0° 9′	1	δ
2.	141° 48′ — 141° 30′ =	0° 18′ feeble	3	γ
3.	141° 18′ — 140° 54′ =	0° 24′ strongest	10	α
4.	140° 48′ — 140° 15′ =	0° 33′	5	β

Cut off at 138° 51′. Violet appears a little.

Diagram of Spectrum of Alkaline Cruentine.



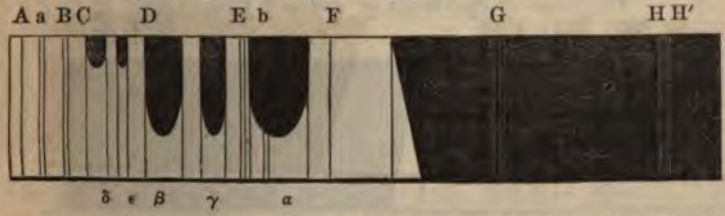
Neutral five-banded Cruentine in Alcohol.—When the preparation from which chloroform extracts the neutral fluorescent cruentine is treated with alcohol, it dissolves easily and almost entirely. The concentrated solution allows a little red to pass; on further dilution three bands appear, ultimately five, one in red feeble, one in yellow also feeble, both narrow, and three dense and dark bands in green, the last one situated at the point of transition into blue.

Neutral five-banded cruentine.

Bands.	Measurements.	Width.	Intensity.	Rank.
1.	142° 18′ — 142° 6′ =	0° 12′	2	δ
2.	142° — 141° 54′ =	0° 6′	2	ε
3.	141° 42′ — 141° 21′ =	0° 21′	7	β
4.	141° 12′ — 140° 58′ =	0° 14′	7	γ
5.	140° 45′ — 140° 12′ =	0° 33′	7	α

Cut off in blue at 139° 24′. (See fig. 10, plate I.)

Diagram of the Spectrum of five-banded Cruentine.



When this solution is made alkaline with ammonia the band 2 disappears, and the others arrange themselves slightly differently, as stated above under neutral cruentine. Band 1 remains in its place, but loses a little on the red side. It measured—

In the primary alcohol solut. 142° 18′ — 142° 6′ = 0° 12′
After addition of NH_3 - 142° 15′ — 142° 6′ = 0° 9′

Band 3 of primary solution also becomes feebler and narrower.

It measured - - 141° 42′ — 141° 21′ = 0° 21′
After addition of NH_3 - 141° 48′ — 141° 30′ = 0° 18′

Band 2, which disappears, coincides with band 1 of acid cruentine sulphate, as the comparison of their measurements will show.

Acid cruent. sulph. β - -	142° — 141° 50′ = 0° 10′
Band 2 of above spectrum -	142° — 141° 54′ = 0° 6′

These considerations admit of some application to the explanation of the spectrum just described. The body is either a neutral dibasic sulphate, or is a mixture of acid sulphate and neutral sulphate, the spectra of which are intermixed, or as it is termed, superposed upon each other. To this latter explanation there is, however, this weighty objection, that the mixture, a five-band body only, is soluble in alcohol, while the four-band body is not soluble in alcohol. Acid cruentine is, however, easily soluble in alcohol. If, therefore, the alcoholic solution contains acid and neutral cruentine, the latter is only dissolved by means of the acid salt, but without loss of its spectrum.

The five and four banded cruentine are both transformed into the three-banded acid cruentine by solution in sulphuric acid. On addition of water the five-banded cruentine is again obtained, which by ammonia becomes four-banded.

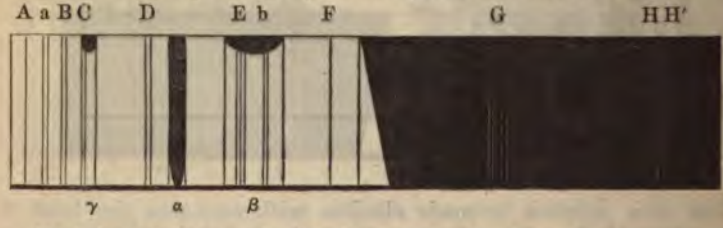
The five-banded cruentine was obtained by extracting with ether and much glacial acetic acid, cruentine many times dissolved in sulphuric acid, and re-precipitated by water. Immediately on washing out the acid by water one band in orange disappeared, the red was more intense, and in fact the ether showed the four-band cruentine spectrum.

Reduced cruentine.

Reduced Cruentine.—Cruentine dissolved in ammonia shows the four bands. When an ammoniacal tartrate solution of iron suboxyde is added to it, it changes its spedtrum in the following manner (see spectrum, fig. 2, plate II.) : There is a pale band 1, in red; possibly there is a shadow in yellow to green, where a rather abrupt transition occurs. There is a prominently dark band, 2, in green, and a broader one, in green towards blue.

Bands.	Measurements.	Width.	Intensity.	Rank.
1.	142° 21′ — 142°	12′ = 0° 9	1	γ
X. if existent, a mere line.				
2.	141° 30′ — 141°	18′ = 0° 12′	10	α
3.	141° — 140°	26′ = 0° 26′	2	β

Diagram of Spectrum of reduced Cruentine.

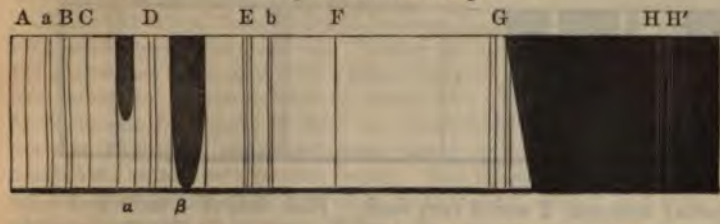


On being shaken with air the solution becomes much lighter, and presents again the spectrum of four-banded cruentine.

When the solution of reduced cruentine is acidified with sulphuric acid it yields a precipitate. After filtration it is much lighter and passes very clear of a pale rose tint. Its spectrum shows the bands represented in fig. 3, plate II.

Band.	Measurement.	Width.	Rank.
1.	142° — 141° 50′	= 0° 10′	β
2.	141° 30′ — 141° 8′	= 0° 22′	α

Diagram of Spectrum of acidified Solution of reduced Cruentine, being Cruentine Sulphate.



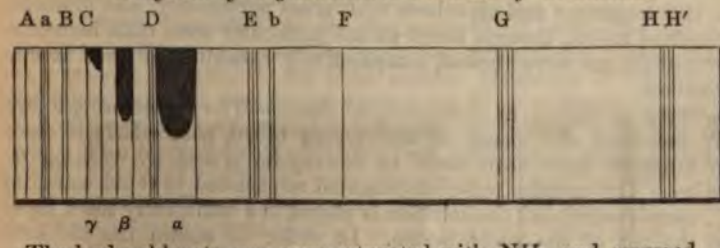
These are the bands of acid cruentine in the dilution where γ has completely disappeared. Cruentine therefore exhibits this peculiar property, that it can be deoxydised (in alkaline) and reoxydised (in acid) solution. During this process, however, much colouring matter is lost by changes not yet scrutinized. In its alkaline solution it is desoxydised and reoxydised as easily as hematocrystalline. It is a most remarkable fact in science that a decomposition product of hematocrystalline of the second order retains what I will term the breathing power of the blood corpuscle.

Cruentine and Hydrochloric Acid.—The chloroform solution treated with HCl and water becomes turbid. Warmed, it clears up and appears more rose-coloured. On cooling it becomes, however, again turbid. Its spectrum shows three bands. Cruentine and hydrochloric acid.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	? — 142° 12′ =	?	3	γ
2 in yellow	142° 3′ — 141° 54′ =	0° 9′	5	β
3 in green	141° 39 — 146° 18′ =	0° 21′	7	α

Green not shaded, blue entire, but appears green. The margins of β are sharper than those of α.

Diagram of Hydrochloric Product of Cruentine.



The hydrochlorate was over-saturated with NH_3 and warmed. The three bands remained the same. The ammoniacal solution was faintly coloured. Ammoniated water did not extract the coloured matter. It is therefore clear that hydrochloric acid effects a permanent change in cruentine.

A combination of calcium-cruentate when decomposed by HCl and extracted by chloroform yielded another spectrum of three bands. Second hydrochloric product.

Band.	Measurement.	Width.	Rank.
1 in red	142° 36′ — 142° 12′ =	0° 24′	α
2 in green	141° 33′ — 141° =	0° 33′	β
3 do.	140° 54′ — 140° 30′ =	0° 24′	γ

V.—ATOMIC WEIGHTS AND DECOMPOSITIONS OF THE ALBUMINOUS SUBSTANCES.

Albuminous substances most condensed.

The most condensed substances are those which constitute the human body. Brain substance, hematocrystalline, fibrine, albumen, have atomic weights varying between 20,000 and 1,612, more or less; that is to say, the sums obtained by the multiplication of the number of atoms of each element with the atomic weight of that element, and by subsequent addition of these products, amount to figures varying between 20,000 and 1,612. Now, as no chemistry is perfect without the knowledge of the atomic weight of substances dealt with, so no attempt at pathological chemistry can be perfect, or lead to important results, which does not base itself upon the atomic weights of the normal substances of the body, and uses them as a measure for determining the atomic weights of the abnormal ones. The comparison shows the amount of change, and if all stages of the change be known or deducible, the nature of the change, that is, the pathological process.

If it were necessary to study the changes of the albuminous matters upon substances only which have resulted from actual pathological processes in living beings, the difficulties of the task would be enormous. For these products are of only transient existence, most of them are as completely consumed or oxydised as the normal substrata; to collect them in quantity sufficient for atomic determination would require hundreds or thousands of operations; in many cases it would be impossible to collect them at all. Under these circumstances chemical methods are applied to the albuminous substances out of the body, by which they are variously decomposed; the products are analysed, and their properties and reactions so well determined, that if they afterwards are met with in pathological products they can be at once identified. These methods are termed *physiolysis* and *chemolysis;* the health standard of comparison is termed *biolysis*, and the process of disease which they are to illustrate is termed *patholysis*. Of biolysis a sketch has been given in a previous chapter. From assimilation to the intermediate cleavage effected by the biliary function, and from this to the final excretion of multifarious products by urine and breath we have seen a connected chain of chemical (synthesis as well as) lysis. Under

Physiolysis.

the term physiolysis we imply a solution of animal substances into proximate nuclei or final products under the influence of the natural agents oxygen, moisture, and heat, in the presence of more or less water. This process, when occurring without regulation under the influence of atmospheric influences is termed putrefaction; but physiolysis means putrefaction regulated by certain designs and precautions, which may preserve proximate products from destruction, collect such as are volatile, and on

Chemolysis.

the whole keep the process as uniform as possible. Chemolysis on the other hand is the artificial and mostly rapid decomposition of animal matters into proximate nuclei by means of chemical agents, which do not themselves undergo any change, but only combine for a time with some of the products, and may ultimately be removed entirely. Hot water, particularly under high pressure, alkalies in water, acids, particularly hydrochloric and sulphuric, have all this chemolytical power. In ordinary experiments sulphuric acid is mostly used, on account of its non-volatility and the possibility of removing it from the solution more completely than other agents. The application of these methods has led to the remarkable result that the products of both physio-and chemolysis do not resemble those of biolysis at all, but resemble those of patholysis; and again, that the products of chemolysis resemble more to those of patholysis than to those of physiolysis, or in other words, that a

sick body is more in the condition of being dissolved in sulphuric acid than in that of being putrefied. But there are exceptions to this, in which putrefaction is closely imitated by the patholytical process. It remains to observe that temperature is a great factor in the sum of results which may be obtained by either process. In the dilute sulphuric acid solution the temperature rises little above that of boiling water; in regulated putrefaction a very low temperature 12° to 19° C. is mostly observed; while in diseases such as fevers a higher temperature, and in others such as cholera a lower temperature, than the normal (max. 38° 6 C., min. 36° 76, mean 37° 6 C.) one is kept up. We cannot doubt that the special dynamicities of the elements of the body are in part at least determined by its temperature, and *vice versâ*, that pathological influences change the dynamicities and consequently the temperature.

Influence of temperature upon lysis.

The mere percental composition of the albuminous substances, albumen, fibrine, and caseine, is almost identical in all three, and would lead to one and the same formula. Nevertheless they differ so much in their chemical behaviour, and in their origin, as far as that is known, that there must be essential differences determinable only by atomic or molecular weight determinations. The silver and zinc compounds of albumen had led Lieberkühn to adopt 1612 as the molecular weight and $\overline{C}_{72}\ H_{112}\ N_{18}\ \overline{S}\overline{O}_{22}$ as the formula of albumen. The researches of Schwarzenbach by means of the platino-potassic cyanide had apparently led to the same result. I therefore repeated these experiments. The platino-potassic cyanide was prepared by dropping a concentrated solution of platinic chloride into a concentrated solution of potassic cyanide, and heating the mixture until the precipitate which formed at first was redissolved. The platinic chloride was reduced by the cyanogen to subchloride, as evidenced by the escape of ammonia carbonate, and nitrogen. On cooling the salt crystallised; it had to be recrystallised. Other modes were also tried, but considered still less satisfactory and more expensive than the foregoing one. The formula of this salt is—

Molecular weight of albumen.

$$2\,(K\ \overline{C}y)\ +\ \overline{P}t\ \overline{C}y_2\ +\ 3\,(H_2\overline{O}).\quad (\overline{C}y = \overline{C}N)$$

In the researches of Schwarzenbach, this salt, when dropped into a solution of albumen previously acidified with acetic acid, produced an insoluble white precipitate, a compound of albumen and platinic cyanide. This left on an average 5·56 per cent. of $\overline{P}t$, leading to 3,236 as the molecular weight of the albumen combined with it. The atomic weight of albumen as given by Lieberkühn and doubled in accordance with the requirements of the didynamic character of the $\overline{P}t$ atom, is 3,224, which differed so little from 3,236 that it could be considered identical with it. But in my own analyses an average of 5·34 per cent. of $\overline{P}t$ was found, which divided by the atomic weight of $\overline{P}t$ (197·4) gave a quotient of 0·0270 instead of the 0·0283, the one required by the theory of Schwarzenbach. This destroyed at once the proportions between $\overline{P}t$ and albumen, and caused me to abandon the research as not likely to lead to final information. Since that time my apprehension has been confirmed by two events. The first are researches by Diakonow, which make it very probable that the irregularities in the composition of the platino-cyanide precipitates of albumen may be still greater than I had found them; and the second is that Schwarzenbach has retracted his statement about the atomic weight of caseine being half that of albumen. The effect of all these analyses and discussions is that inquiry is anew directed to the methods which I have adopted in the following for getting at the atomic weight of the albuminous substances.

Physiolysis of Fibrine.

Decomposition of fibrine.

As the products of putrefaction take a considerable share in the effects of wounds and dyscrasias their study was continued upon fibrine. The fibrine was allowed to decompose in its wet state, without any additional water, in loosely covered glass vessels in a cool place. On analysis it yielded many of the matters already described by Bopp, and in addition some new ones. The fibrine had deliquesced, and its watery solution with some acetic acid and boiling yielded albumen This phenomenon goes far to support the theory of the formation of fibrine above related, according to which it contains two albuminous nuclei, and would therefore have an atomic weight of about double that of albumen. But as other derivations are not excluded, and the formation of fibrine as well as its physiolysis have never been investigated quantitatively, no certain deductions can be made. Caseine or boiled flesh yield no soluble albumen by physiolysis. The fluid derived from the decomposed fibrine by mixing with water was turbid, contained myriads of infusorial beings, particularly vibriones, and a suspended organic matter, which made filtration almost impossible. From this I extracted cholesterine by alcohol. This might possibly be derived from some white blood corpuscles, which it is almost impossible entirely to exclude from the fibrine, but its quantity seemed to be greater than this surmise could account for. By treatment with lime volatile alkalies,* particularly ammonia and trimethylamine, the latter in small quantity, were evolved, accompanied by a crystalline matter which was soluble in ether and had a powerful and disagreeable odour. By treatment of the residue with acid, valerianic, butyric, and a small quantity of other acids were obtained. From the fluid I extracted, with ether, a brownish red oil, soluble in hot, insoluble in cold water, soluble in spirit, which was an acid, and formed a pitchlike salt when treated with lead acetate. From the evaporated fluid leucine was extracted, then there remained a syrup, which was soluble in alcohol and precipitated by ether, dissolved earths and acids like the syrupy acid (fluorescentic acid, see below) obtained by sulphuric acid chemolysis of albumen, but was distinguished from it by yielding with sulphuric acid tyroine. This latter body therefore remains longer attached to the original main nucleus in putrefaction than in chemolysis. The most important of the above products of this research were destroyed by an incipient conflagration which unfortunately took place at the laboratory during a hot summer noontide.

Yields albumen.

Other products.

Chemolysis of Albumen.

Chemolysis of albumen.

The decomposition of albumen by artificial chemical means or chemolysis is a more practical way than the former, as being less disagreeable to the senses of the operator and requiring less time. I have repeated and amended almost every known process, and on that account alone the results would possess some value. They claim, however, more attention on account of the discovery of six well-defined new and highly interesting chemical compounds, which I will shortly describe.

Of materials, fibrine, albumen, and yelk of egg, caseine, blood, cows, and human hair, camels' hair, horn shavings and horn dust, and a great

* Some years ago Crace Calvert announced in the Proceed. Royal Soc. that he had obtained from putrefying meat and fish, volatile alkalies containing sulphur and phosphorus. In my researches I have never met with such volatile alkalies, and think it very questionable whether they do actually exist. The volatile crystalline matter may contain sulphur and phosphorus, but is not an alkali.

variety of human and animal organs were employed. As decomposing agent I mostly used sulphuric acid, but also caustic potash. By the acid treatment there was obtained a brown substance, soluble somewhat in acids, easily in alkali, reprecipitated by acetic acid in brown flakes, which when dry form a brownish black powder. (Possibly fluopittine, defined below, may stand in some relation to this brown matter.) It is questionable whether it corresponds to the insoluble matter suspended in putrefying albumen and fibrine. A small quantity of volatile acids was obtained and combined with barium. They have not yet been analysed any further. Next large quantities of volatile alkalies were collected. These consisted mainly of ammonia, but a peculiar smell of seafish, and blackening of the salts on evaporation, led to further scrutiny, whereby some trimethylamine, C_3H_9N, was isolated. (Platinum in the chloride combined with platinic tetrachloride=37·20 per cent.) By repeated extraction with alcohol, and recrystallisation and reprecipitation with platinic chloride, salts were successively obtained which contained 39·20 per cent. $\not{Pt}$, 39·14 per cent. Pt, and corresponded to dimethylamine-chloride-platinic chloride. A salt was further obtained yielding 42·56 per cent. of $\not{Pt}$, being nearest to the theory of monomethyl ammonium Cl $\not{Pt}$ Cl_4, which requires 41·87 per cent. of $\not{Pt}$. Further a compound was frequently obtained containing 42·23 per cent. to 42·28 per cent., 42·85 per cent., 42·0 per cent. of $\not{Pt}$, and corresponding to a salt or mixture in atomic proportions of 1 atom of trimethyl-ammonium—chloride—platinic chloride, and 3 atoms of ammonium—chloride—platinic chloride. In most of these salts the carbon and hydrogen were also determined by elementary combustion. I am of opinion that the immediate products of the chemolysis of the albuminous matters contain far more complicated alkalies than those above obtained. During the boiling with lime large quantities of gas of peculiar smell are constantly evolved, being volatile hydrocarbons not absorbable by water or acid. The condensed hydrochlorates of the alkalies become black during every evaporation. Consequently a decomposition is constantly taking place, leaving ultimately pure ammonia. We shall see that neurine, a base obtained from brain-matter, yields by decomposition trimethylamine, and can be artificially prepared from it. I have no doubt that albuminous matters as well as cerebric acid yield neurine, and that the compound ammonias above described are derived from some such proximate product of decomposition. A most remarkable product of this chemolysis was a new alkaloid, to which, from its most striking power of fluorescence, I gave the name of fluorescentine. This is a white solid, deposited in little rosettes of leaves and globules. It is little soluble in water, little soluble in ether, more easily soluble in alcohol. It dissolves easily in dilute sulphuric and other acids, and is precipitated from this solution by iodine in crystalline needles of green and gold colour. It is quickly altered by even moderate heat, least in its watery sulphuric acid solution, most in a concentrated alcohol solution when it is evaporated on the steam bath. Its power of fluorescence (violet blue) is not destroyed by any solvent, acid or alkali, which does not absolutely destroy the substance itself. Accompanying fluorescentine is a substance termed parafluine, which is red, amorphous, readily soluble in alcohol and ether, but insoluble in water and dilute sulphuric acid. It is accompanied by a matter having a powerful odour, causing great irritation of the nose and eyes, and in a concentrated state spasms of the muscles of the eyes and lacrymation. Its odour and action are like those of a mixture of mustard and garlic oil. By the same process

Materials.

Products.

Volatile acid

Volatile alkalies.

Methylated ammonias.

Description more complicated alkalie

Fluorescenti

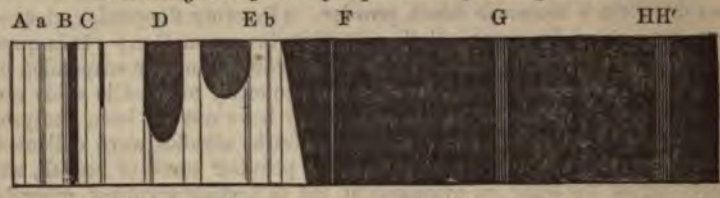
Parafluine.

Irritating substance.

Fluopittine.

another product, fluopittine,* is obtained. Fluopittine, insoluble in dilute sulphuric acid and in ether, is easily soluble in alcohol. The solution

Intensity Diagram of Spectrum of Fluopittine.



has a reddish brown colour, and properly diluted yields a remarkable spectrum. This shows two absorption bands in red which are thin like sun-lines, and two broader bands in green. (See Plate IV. fig. 3.)

1 = β. 3 = α.
2 = δ. 4 = γ.

Possibly it is only the resinous product of the decomposition in overheated alcoholic solution of fluorescentine. It is at present impossible to discuss the significance of any of these substances. But it is remarkable that the extracts of tetanus organs and of the parts from cholera bodies yielded a small quantity of fluorescentine.

I instituted a careful discussion of the phenomena of fluorescence exhibited by the new bodies, and a comparison with the "animal quinoidine" discovered by Drs. Dupré and B. Jones. The latter has a purely sky-blue fluorescence, and is made optically inert by hydrochloric acid, like quinine. It differs, therefore, greatly from fluorescentine.

Importance of fluorescence phenomena.

The phenomena of fluorescence will in future yield important means of diagnosis in animal chemistry. When speaking of urochrome I shall have to describe two of its products, which yield absorption and fluorescence phenomena in the spectrum and condensed sunlight. Possibly fluorescentine may be the chemolytic form of that particular part of the nucleus of albumen, which in the course of biolysis leads to urochrome, and by the chemolysis of the latter to omicholine and omicholic acid.

Thiotherine.

I further extracted from the albumen products a crystallised substance containing sulphur, thiotherine; as the process is at present only small quantities are obtainable, 70 pounds of acid and 50 pounds of hair having yielded me only a few grains.

Fluorescentic acid.

There was also extracted an uncrystallisable acid, fluorescentic acid, which seems to be the basis of all albuminous substances. This was studied in many ways, like all the other new substances, but the technical details of these inquiries have to be excluded from the present account. Of other known matters, tyroine, leucimide, and leucine were extracted.

---

* This was found to be very similar to the spectrum of cholonematine, a particular biliary coloured matter (reported, B. II., from Norman), part soluble in ether. This also had the two thin lines, but reversed in order, the thinnest being towards the red end, and two broad bands in green.

1 = δ
2 = α
3 = β
4 = γ

Cut off at blue, even in very dilute solution. See p. 229.

If fluopittine were a derivate from tyroine by the influence of iodine, the similarity of its spectrum with that of the biliary matter would be more easily explained. For tyroine contains only one atom of water more than cholophæine, and might therefore yield similar derivates as the latter.

In order to decide whether thiotherine was not merely a mixture of leucimide with some sulphurous body, I instituted some researches on leucimide. It was produced from leucine by a reaction, which also yielded an oil and amylamine, together with leucine hydrochlorate. Five elementary analysis showed it to be $C_6 H_{11} NO$. Consequently it contained an atom of water less than leucine. It could not have any relation to thiotherine, which contained 19·9 per cent. of sulphur. Of tyroine* many reactions were studied. The product of its action upon mercurous nitrite, which is dark red, was subjected to spectral analysis. It showed no special absorptions. Erythrosic acid from tyroine by nitrous acid was found to be an acid, and its insoluble barium-salt was obtained and partially analysed. The product of the destructive distillation of tyroine hydrochlorate was found to have great fluorescence, to crystallise and dissolve in alcohol. On leucine many researches were instituted which yielded most interesting and useful results. A new mode of purifying it yielded technical facilities, which were used in the production of a considerable amount of pure leucine, to be used in future experimental pathological inquiries, particularly those relating to rheumatic fever and endocarditis by acids of the lactic acid series. Leucine ($C_6H_{13}NO_2$) is an amido-acid. It occurs in so many parts of the body under such a variety of circumstances, that some methods for its better and more complete isolation were highly desirable. I therefore studied its compounds, and found that the copper compound seemed to offer facilities for that purpose. In studying this compound I obtained several new combinations with that metal, which I will shortly characterise.

Leucimide. .. Tyroine. Leucine.

Dicupric trileucine, $C_{18}H_{35}Cu_2N_3O_6$ with 24·58 per cent. Cu required, and 24·47 found; 8·1 per cent. N required and 8·3 per cent. found. Monocupric dileucine, $C_{12}H_{25}CuN_2O_5$ with 18·55 per cent. Cu found, 18·56 required. Both these salts were obtained by various proceedings; one exhibited the power of leucine to displace hydrochloric acid. To leucine hydrochlorate oxyde of copper was added to saturation; the solution was evaporated. Ultimately all leucine was combined with copper, all acid was volatilized. Monocupric trileucine $C_{18}H_{37}CuN_3O_6$, 13·95 Cu required, 14·38 per cent. found, was obtained by boiling with water monocupric dileucine. Under these circumstances the neutral salt breaks up as follows :—

Copper-compounds of leucine.

$$\left\{\begin{matrix}\tilde{L}\,\tilde{L}\\ \end{matrix}\right\}\left\{\begin{matrix}\tilde{L}\,\tilde{L}\\ Cu\end{matrix}\right\}\left\{\begin{matrix}\tilde{L}\,\tilde{L}\\ Cu\end{matrix}\right\} = \left\{\begin{matrix}\tilde{L}\,\tilde{L}\,\tilde{L}\\ Cu\end{matrix}\right\} + \left\{\begin{matrix}\tilde{L}\,\tilde{L}\,\tilde{L}\\ Cu\,Cu\end{matrix}\right\}$$

3 atoms monocupric dileucine. — 1 atom monocupric trileucine. — 1 atom dicupric trileucine.

Cu = 18·56 per cent. Cu = 13·95 per cent., Cu = 24·58 per cent.

The mercury compounds were very variable, one quite insoluble in cold and boiling water was found to be pentamercuric hexaleucine $C_{36}H_{65}Hg_5N_6O_{12}$; Hg required 57·94 per cent., found 57·09 per cent.

* Formerly termed tyrosine, but the terminal "s" of tyros not belonging to the root, has for grammatical reasons no place in the compound.

cholesterine. The powder is exhausted with alcohol, lastly, on the filter placed in a hot funnel, until the alcohol is only faintly yellow, and on evaporation leaves only a little colouring but no resinous matter. The exhausted powder is now treated with cold dilute hydrochloric acid, which causes the evolution of carbonic acid and sulphuretted hydrogen. It is better to allow the acid to act upon the powder for some days at the ordinary temperature, than to increase its dissolving power in time by the employment of heat. The powder is washed by decantation, lastly, on the filter, and treated a second time with alcohol. It now extracts but little biliary acid, but a brown colouring matter, which has evidently been set free by the acid (mainly bilirubine), which is slightly soluble in alcohol. After complete exhaustion with alcohol the residue may yet be treated with ether, but if the former operations have been completely performed this agent will extract little or nothing besides a little bilirubine.

Treatment with hydrochloric acid.

Second treatment with alcohol.

Extraction with ether.

After drying the powder is of a fine reddish yellow colour, which speedily becomes red or brownish red when exposed to the light. It is now boiled with pure chloroform, free from water and hydrochloric acid, care being taken to condense and cause to flow back into the flask the evaporated chloroform. The chloroform solution may now be filtered off, and the residue from the filter returned into the flask, to be anew boiled with chloroform. Large quantities of chloroform are of necessity lost during this operation. The powder may also be placed into a so-called exhauster, but then the advantage of being able to boil the chloroform with the powder is lost.

Drying.

Boiling with chloroform.

Modus operandi.

The following mode of operating is the most advantageous:—The solution obtained by boiling is allowed to stand at rest with the powder in the closed flask for 24 hours. After that time all powder has collected on the top of the fluid; the clear dark red solution fills the bottom of the flask. This solution is now drawn off by means of a syphon fixed in a cork, which closes a second flask, and which is partly emptied of air by suction with the mouth through a second tube piercing the cork, after the free end of the syphon has been immersed to the bottom of the flask containing the powder and solution. The fluid thus drawn off is obtained perfectly clear by filtration through paper. From the red solution most of the chloroform is distilled off in the water-bath. The residue is placed on a filter, washed with chloroform, then with absolute alcohol until the latter is nearly colourless, and the residue on the filter purely red, without any admixture of green. The colouring matter thus obtained is magnificently red, and of exactly the same appearance as the red oxyde of mercury obtained by heating the nitrate. Absolute alcohol and ether extract from it no heterogeneous substance, and only little of the colouring matter itself. But it is well to purify it once more by solution in chloroform, and precipitation of the concentrated solution by absolute alcohol.

Purification.

After the chloroform has repeatedly acted upon the gallstone powder the amount of colouring matter extracted by each operation becomes exceedingly small. It is then advisable to treat the dried powder again with dilute hydrochloric acid, to wash it with water and spirit, and after drying to resume extraction with chloroform; or the dried powder may be treated with an alcoholic solution of caustic potash. The colouring matter dissolves with a dark reddish brown colour, and can easily be separated from the sediment of impurities by filtration. The filtrate after acidulation with hydrochloric acid deposits the red colouring matter in flakes, which are quickly collected on a filter, and then boiled in absolute alcohol or shaken with chloroform. After cooling the precipitate is collected on a filter, and washed with absolute alcohol. It

Repeated extraction with H Cl.

Precipitation.

is a yellowish powder, which owing to its finely subdivided state quickly becomes green on the surface by oxydation. In that case it must be again treated with absolute alcohol. The chloroform washings, which are dark green, should after distillation of some chloroform be precipitated with absolute alcohol, to obtain the rest of bilirubine. From the various mother liquors much green colouring matter may be obtained, particularly from the first alcoholic acid solution, by addition of water.

Biliphæine and bilirubine.

Biliphæine and Bilirubine.—Before the discovery of the use of chloroform as a solvent of the colouring matter, only brown modifications of this substance were known and obtainable by the several processes then in use, particularly that employed by Heintz. These brown matters were termed biliphæine or cholophæine, according to the more or less puristic tendencies of authors. When, however, the red colouring matter was obtained by means of chloroform, it was generally assumed that the brown colour of former preparations had been a sign of impurity. The red colouring matter accordingly went by the name of cholerythrine or bilirubine, and was believed to be the only form of pure colouring matter of bile.

During many operations for the isolation of pure colouring matter of bile I regularly obtained two modifications, one being reddish brown, the other of a purely red colour, like nitric oxyde of mercury. The brownish red products were kept apart for further purification. The purified product showed a darker, somewhat purple brown colour, but in all other respects behaved like the purest bilirubine. On microscopic examination it was found to consist of large crystalline particles, mixed with many perfect crystals. The bilirubine on the other hand consisted almost entirely of minute amorphous granules ; only when it had been precipitated by alcohol it showed minute yellow rhombic prisms. When the mixture of chloroform solution and alcohol, from which the first or immediate precipitate of bilirubine had been removed by filtration, was allowed to stand and mixed gradually with some more alcohol, it deposited another quantity of colouring matter partly red, partly brown, the former amorphous, the latter in large crystals united to clusters. The brown crystalline part could be separated by lævigation with alcohol, in which it settled quicker than the red matter.

Crystals of cholophæine.

The crystals thus isolated had a dark reddish brown colour ; their surfaces reflected the light with a purple and steel blue glitter. They were opaque under the microscope ; thin scales appeared reddish or red ; the very thinnest crystals, of which there were few, transmitted the light with a yellow colour. The crystals were mostly from one-tenth to one-eighth of an inch in length, of from one-twentieth to one-thirtieth of an inch in width, and their third diameter was probably from one-hundredth of an inch to immeasurable thinness. By their form they belonged to the rhombic system, being prisms in some crystallisations simple and with obtuse nearly right angles, in others with sharp angles on the one, obtuse angles on the next edge, and planes from secondary prisms cutting off the sharp angles of the primary ones.

The most minute crystals of bilirubine also showed the same shape, and were of a yellow colour. The red modification could by cautious crystallisation always in part be transformed into the brown. Without special elementary analysis of the two modifications, it may be considered as proved that this colouring matter appears in two modifications, a crystallized or crystalline one of purple brown colour, cholophæine or biliphæine, and an amorphous one of a bright red colour, bilirubine.

This observation will explain the discrepancies concerning this substance which have existed in the writings of many authors. It disproves the statement of Städeler that the pure colouring matter of bile

was red only, and that when a product of this kind was not red but brown and crystallised it was impure.

In the following I shall consider cholophæine and bilirubine as identical chemical substances: but whenever the one or the other name is used in the description of a process, the reader will understand that the modification indicated by the name has been taken for the experiment.

Influence of light.

The red nearly orange coloured amorphous colouring matter when exposed to light, while all moisture is carefully excluded, gradually assumes a brown colour on its surface. In the interior the powder remains unchanged for a long time. When boiled with water for some time it assumes the same brown colour. In water it is quite insoluble,

Solubility.

slightly soluble in boiling absolute alcohol, with a yellow colour; on filtration through paper the colouring matter of the first portions of alcoholic solution remains adhering to the paper fibres, and the alcohol passes nearly white.

In ether it is very little soluble, somewhat easier in sulphide of carbon and benzole. The best solvent is chloroform, of which 512 parts dissolve about one part of colouring matter. The rays of the sun discolour the chloroform solution; the addition of hydrochloric acid produces a precipitate in it.

Bilirubine when prepared as above and dried in vacuo lost yet some water and then was constant. By many variegated elementary analyses

Composition.

its composition was ascertained to be $C_9 H_9 NO_2$.

Atoms.	Atomic Weights.	In 100.
9C	108	66·26
9H	9	5·52
N	14	8·59
2O	32	19·63
	163	100·00

Compounds of Cholophæine.

Neutral silver salt.

Neutral Monohydrated Cholophæinate of Silver. — A neutral solution of cholophæine in ammonia, prepared by digesting dilute ammonia solution in water with excess of cholophæine, was precipitated with nitrate of silver. The precipitate was of a reddish brown colour, and after washing with water was dried in the vacuum over sulphuric acid, light being completely excluded.

The mean of several determinations gave 37·39 per cent. of silver.

Taking into consideration that the analyses of cholophæine or bilirubine led to the empirical formula $C_9 H_9 NO_2$, there cannot be any doubt but that the quantity of silver found in the cholophæinate is exactly that required by a neutral monohydrated compound of the formula $C_9 H_{10} Ag NO_3$. However anomalous may be a silver salt containing an atom of water, it is now certain that the composition and molecule of cholophæine is expressed by the formula $C_9 H_9 NO_2$.

Theory of cholophæinate of silver dried in vacuo $= C_9 H_{10} Ag NO_3$

Symbols.	Atomic Weights.	Per Cents.
O_9	108	37·50
H_{10}	10	3·47
Ag	108	37·50
N	14	4·86
C_3	48	16·67
	288	100·00

Basic Anhydrous Cholophæinate of Silver. — An ammoniacal solution of cholophæine (which cholophæine had been repeatedly purified by solution in chloroform and in caustic potash and alcohol) was treated with nitrate of silver. No precipitate appearing an excess of silver was added, and then some nitric acid to neutralize as nearly as possible the excess of ammonia. A precipitate now formed, the solution became perfectly colourless, and the precipitate was washed with water. It was dried in vacuo at 130° C.

Basic silver salt.

It is thus shown that cholophæinate of silver is soluble in free ammonia, and that when the ammoniacal solution, in the presence of an excess of silver-solution, is neutralized down to a proper degree, the basic salt falls down. Its theory is derived from the data concerning free cholophæine, the neutral silver-salt, and from direct analysis its formula is $C_9 H_7 Ag_2 NO_2$. In this compound two atoms of hydrogen are replaced by two of silver. An analogous lead compound in which the two atoms of hydrogen are replaced by one didynamic atom of lead will be described lower down. Its formula is $C_9 H_7 Pb NO_2$, and its production strengthens the presumptions in favour of the basic silver compound.

Theory of basic cholophæinate of silver dried in vacuo = $C_9 H_7 Ag_2 NO_2$.

Symbols.	Atomic Weights.	Per Cents.
C_9	108	28·64
H_7	7	1·85
Ag_2	216	57·29
N	14	
O_2	32	
	377	

Neutral Cholophæinate of Barium.—An ammoniacal solution of cholophæine with excess of ammonia was precipitated by chloride of barium. The dark greenish brown precipitate was washed until the filtrates were free from barium ; the filtrates were all somewhat green coloured, and on standing deposited green flakes. The compound was dried at 100°, and formed a dark brown powder.

Neutral barium salt.

The analyses yielded data corresponding to the requirements of a barium compound, which is strictly analogous to the neutral silver-salt, containing a didynamic atom of barium, which solders together two molecules of cholophæine by replacing one atom of hydrogen in each of them ; two molecules of water are superadded.

Theory of barium cholophæinate = $C_{18} H_{20} Ba N_2 O_6$.

Symbols.	Atomic Weights.	Per Cents.
C_{18}	216	43·46
H_{20}	20	4·02
Ba	137	27·56
N_2	28	,,
O_6	96	,,
	497	

Half-acid Cholophæinate or Sesqui-cholophæinate of Barium.— This salt, prepared by precipitation from a neutral ammoniacal solution by $BaCl_2$, washing with water, treating and boiling with alcohol until the alcohol on filtration and washing passed clear and colourless, was dried

Half-acid barium salt.

APPENDIX. in the steam closet. It remained of a brownish red colour, but after being powdered it became of a darker brown colour on the surface during drying. Dried at 100° until constant, and then at 110° C., it yielded on analysis data which showed that in this cholophæinate one atom of barium is in combination with three molecules of cholophæine. If to the dihydrated neutral cholophæinate of barium described above we add one molecule of cholophæine, thus—

1 cholophæinate of barium $C_{18} H_{20} Ba N_2 O_6 = 497$ At. W.

1 cholophæine $C_9 H_9 N O_2 = 163$ „

We obtain - - $C_{27} H_{29} Ba N_3 O_8 = 660$ „

To the theory of this compound the above analyses exactly correspond, as is evident from the following comparison :—

Symbols.	Per Cents.	Found Mean.
C	49·09	50·63
H_{29}	4·39	4·37
Ba	20·75	20·66
N_3		
O_8		

By the following ... ferences in the composition of the neutral and the ... ate of barium will be exhibited in a striking manner.

Neutral Cholophæinate of Barium. $C_{18}H_{20}BaN_2O_6$ Atom W. = 497.			Half-acid Cholophæinate of Barium. $C_{27}H_{29}BaN_3O_8$ Atom W. = 660	
	Theory	Found.	Theory.	Found.
C	43·46	44·58	49·09	50·63
H	4·02	3·98	4·39	4·37
Ba	27·56	27·55	20·75	20·66

Neutral calcium salt.

Neutral Cholophæinate of Calcium.—The excess of cholophæine, which had served to make the neutral-ammoniacal solution used for the production of cholophæinate of silver, was dissolved in a slight excess of ammonia and precipitated by chloride of calcium. The precipitate was red. Dried at 100° it yielded on analysis data which are given at length in the paper. Calculating from these data a formula, we obtain a neutral cholophæinate of calcium $C_{18} H_{20} Ca N_2 O_6$, which is in every respect analogous to the neutral barium compound above described. We must assume in it the existence of two molecules of water, which are not expelled even at the temperature of 100°. The following comparison of theory with the analytical data will make the correctness of these conclusions more conspicuous :—

Symbols.	Atomic Weights.	Per cents.	Found Mean.
C_{18}	216	54·00	53·86
H_{20}	20	5·	4·90
Ca	40	10·	10·17
N_2	28		
O	96		
	400		

Half-acid Cholophæinate or Sesqui-cholophæinate of Calcium.—I had first of all cholophæinates prepared the barium salt, which was found to be a sesqui salt. The neutral calcium salt was next obtained, and indicated the existence of two classes of salts, neutral and half-acid. The correctness of this conclusion was put to the test by the endeavour to obtain the neutral barium salt, and the experiment proved successful. It was next necessary to obtain the half-acid cholophæinate of calcium. A neutral solution of bilirubine was therefore precipitated by chloride of calcium washed and dried.

Half-acid calcium salt.

The compound was found to be analogous to the half-acid barium compound already described, and has the formula $C_{27}H_{29}CaN_3O_6$, and the following theory :—

	Theory of atoms.	Theory of per cents.
C_{27}	324	57·54
H_{29}	29	5·15
Ca	40	7·1
N_3	42	
O_6	128	
	563	

The following comparison exhibits the differences in the composition of the neutral and the half-acid cholophæinate of calcium.

Neutral Cholophæinate of Calcium. $C_{18}H_{20}CaN_2O_6$ At. W. = 400.		Half-acid Cholophæinate of Calcium. $C_{27}H_{29}CaN\,O_6$ At. W. = 563.	
Theory.	Found.	Theory.	Found.
C 54·	53·86	C 57·54	60·37
H 5·	4·9	H 5·15	5·74
Ca 10·	10·17	Ca 7·1	6·91

Explanation of Städeler's error.

In his researches on the colouring matter of human gallstones, Städeler produced a combination of bilirubine with calcium, which on analysis yielded him 9·1 per cent. of calcium oxyde. Assuming this compound to be the normal neutral salt, he allowed the atomic weight of bilirubine to be thereby determined, and rejecting his former analyses of crystallized cholophæine as given in Frerich's Treatise on Diseases of the Liver, he abandoned the empirical formula $C_{16}H_9NO_4$, and substituted $C_{32}H_{18}N_2O_6$ as the formula of the bilirubine, and $C_{32}H_{17}CaN_2O_6$ as that of bilirubate of calcium. (The foregoing three formulæ are given in the old notation.) As this formula is supported by only one, and that a very unsatisfactory calcium determination, and as all the analyses of Städeler concerning bilirubine or cholophæine can be brought into harmony with my results, I can have no hesitation in considering his formulæ, both of bilirubine and bilirubate of calcium, as erroneous. The bilirubate analysed by Städeler was evidently the sesquisalt.

Theory of $C_{27}H_{29}CaN_3O_6$ requires		Städeler found	
CaO	or Ca	CaO	or Ca
9·94 per cent.	7·1 per cent.	9·1 per cent.	6·5 per cent.

With Städeler's formula of bilirubine fall the formulæ of all other substances described by him under the names of biliverdine, biliprasine, bilifuscine, and bilihumine.

It remains to point out in this place the circumstances under which cholophæine will form half-acid, neutral, or basic salts. A watery solution of ammonia which is saturated with cholophæine by digestion with an insoluble excess yields on the addition of neutral salts of metals the sesquisalt. Possibly the ammonia salt is itself a sesquisalt while dissolved in water. From somewhat alkaline solutions the basic salts of silver and lead are precipitated by the opportune addition of an excess of metallic salt. But neutral salts of earths added to solutions containing excess of ammonia precipitate the neutral compounds with earths.

Zinc salt.

Cholophæinate of Zinc.—A neutral ammoniacal solution of cholophæine was precipitated with sulphate of zinc. The reddish brown precipitate was easily washed, and quite insoluble in water. Dried at 100° C. it was subjected to analysis. From the amount of zinc found it is evident that this compound is constructed upon the plan of the half-acid salts of calcium and barium. Thus—

1 neutral cholophæinate of zinc	$C_{18}H_{16}ZnNO_4$	
2 water - - -	H_4	O_2
1 cholophæine - -	C_9H_9	NO_2
1 molecule half-acid cholophæinate of zinc -	$C_{27}H_{29}ZnN_3O_8$	

Theory of $C_{27}H_{29}ZnN_3O_8$

Atoms.	Sums of Atomic Weights.	Per cents.
C_{27}	324	,,
H_{29}	29	,,
Zn	65	11·05
N_3	42	
O_8	128	
	588	

Neutral lead salt.

Neutral Cholophæinate of Lead.—Precipitated from a neutral solution by acetate of lead. Dried at 100°. Figures were obtained which keep in proximity of those required by a neutral dihydrated cholophæinate $C_{18}H_{20}PbN_2O_6$. At. W. = 567, Pb = 36·50 per cent.

The half-acid cholophæinate of lead $C_{27}H_{29}PbN_3O_8 = 730$ requires 28·21 per cent. of Pb.

Basic lead salt.

Basic Cholophæinate of Lead.—The compound was precipitated by acetate of lead in great excess from a neutral ammoniacal solution of cholophæine (rubine), which, although it did not dissolve any more cholophæine, smelled of ammonia, and had an alkaline reaction. Dried at 100° C.

This compound may be explained as being a basic cholophæinate, or cholophæine, in which two atoms of hydrogen are replaced by one didynamic atom of lead.

Atoms.	At. Weights.	Per cents.	Found Mean.
C_9	108	,,	,,
H_7	7	,,	,,
Pb	207	56·25	58·1
N	14		
O_2	32		
	368		

This compound corresponds to the basic-cholophæinate of silver, or binargentic cholophæine, described above, $C_9H_7Ag_2NO_3$.

Neutral Cholophæinate of Copper.—This salt was precipitated by sulphate of copper from a neutral solution.

Basic Cholophæinate of Copper.—This salt was obtained by precipitating an ammoniacal solution with excess of acetate of copper.

The only probable formula for this compound is that of a cholophæinate containing 2 cholophæine and 3 copper.

Neutral copper salt.

Basic copper salt.

Atoms.	Atomic Weights.	Per Cents.	Found.
C_{18}	216	,,	,,
H_{12}	12	,,	,,
Cu_3	190·5	37·31	38·70
N_2	28		
O_4	64		
	510·5		

On Cholochlorine, or Biliverdine.

When bilirubine is dissolved in caustic potash and exposed to the air it becomes gradually green. This change can be accelerated by warming the solution and passing a current of air through it. When in thin layers it is purely green, without any admixture of red or yellow, the reaction is complete. On addition of hydrochloric acid a green matter is precipitated in flakes, which is first washed by decantation, and lastly edulcorated on the filter. This is biliverdine.

Mode of producing biliverdine.

Chemical Properties.—Biliverdine is easily soluble in alcohol, with a splendid green colour, particularly while in the wet state; after drying it is soluble with great difficulty only; it is more soluble in hot than in cold alcohol. It is soluble in hydrochloric acid, forming a green solution, in which platinum-tetrachloride and mercury dichloride produce amorphous green precipitates. A quantity of alcoholic solution boiled down with tincture of iodine, and the residue shaken with dilute caustic potash, left a greenish-black resin, which was not soluble in sulphuric acid except under evolution of sulphurous acid, indicating decomposition. By reducing agents the biliverdine cannot be retransformed into cholophæine. Dissolved in caustic potash and treated with hydrothion it assumes a greenish-brown colour, but the original red is not produced. When metallic zinc is added to a solution of biliverdine in hydrochloric acid, the green colour disappears and gives way to a brownish-red one, but the produce is insoluble in chloroform. An alkaline solution treated with sodium-amalgam changes its colour to a reddish brown, and a small quantity of a brown matter is deposited in flakes. But the reddish-brown matter on exposure to air does not become green again. Hydrochloric acid precipitates a brown flaky matter from the alkaline solution.

Chemical properties.

Soluble in alcohol in HCl.

Reducing agents.

When chlorine gas is passed into water containing biliverdine in suspension, dark yellow flakes are obtained, which while insoluble in water and ether dissolve easily in alcohol. When a few bubbles of chlorine gas are conducted into an alcoholic solution of biliverdine the dark-green fluid is instantaneously discoloured. After evaporation of the alcohol yellowish white flakes remain, which by a gentle heat fuse to a reddish yellow mass. They contain chlorine, and are a mixture of at least three compounds, which can be separated by chloroform.

Effect of chlorine.

Biliverdine when repeatedly purified and subjected to variegated analyses gave data which led to the formula $C_8H_8NO_2$.

Composition.

No. 7.
On Chemical Identification of Diseases, by Dr. Thudichum.

	Theory of atoms.	Theory in 100.	Mean found.
8 C	96	63·57	62·94
9 H	9	5·96	6·13
N	14	9·27	9·34
2 O	32	21·20	22·10
	151	100·00	100·00

This shows that biliverdine arises from bilirubine by the addition of 2 oxygen, and the subsequent subtraction of 1 carbonic acid.

Bilirubine. Oxygen. Biliverdine. Carbonic Acid.

$$C_9H_9NO_2 + 2O = C_8H_9NO_2 + CO_2.$$

New test for biliverdine.

On boiling an alcoholic solution of biliverdine with caustic ammonia and nitrate of silver, a reduction of the dissolved silver oxyde is observed. The solution remains green, but on addition of an acid, such as nitric, hydrochloric, or sulphuric, assumes a splendid purple colour. The new body produced is a product of oxydation and termed bilipurpine.

Bilipurpine.

Various reactions.

The alcoholic solution of biliverdine is not altered by boiling with red oxyde of mercury. Lead peroxyde immediately changes its colour to brown, and precipitates a portion of the dissolved matter. The same change of colour without any accompanying precipitation is produced by peroxyde in the presence of ammonia. Peroxyde of lead and sulphuric acid changes the colour of the alcoholic solution to a light yellow, and evolves aldehyde and acetic ether from the alcohol.

Compounds of biliverdine.

Biliverdine dissolves easily in caustic alkalies, and is not precipitated from their solution by any metallic salt. A saturated solution in alcohol gives a precipitate with baryta water. When this reagent is added until a sample filtrate is only pale green, and boiled, all biliverdine is in combination. It must be filtered quickly, air being excluded, and washed with strong alcohol. It cannot be washed with water as the purer it becomes the more soluble it is, and if washing with water were indefinitely continued it would be dissolved entirely. The analyses of this salt led to the conclusion that it contains three molecules of biliverdine and one didynamic atom of barium, and has the formula $C_{24}H_{27}BaN_3O_7$, or $C_{24}H_{27}BaN_3O_6 + H_2O$. This is half-acid biliverdate with one atom of water, according to the following theory:—

1 mol. neutral biliverdate	$C_{16}H_{16}BaN_2O_4$	= 437
1 mol. biliverdine	C_8H_9N O_2	= 151
1 mol. water	H_2 O	= 18

1 mol. of half-acid biliverdate, $C_{24}H_{27}BaN_3O_7$ = 606

Atoms.	At. Weights.	Per Cents.	Mean found.
24 C	288	47·52	48·79
27 H	27	4·45	4·38
Ba	137	22·60	22·41
3 N	42		
7 O	112		
	606		

If the one atom of water be omitted from the calculation, the theory of carbon corresponds better with the experience, but that of the barium less well.

Atoms.	At. Weights.	Theory of per Cents.	Mean found.
C_{24}	288	48·97	48·79
H_{25}	25	4·25	4·38
Ba	137	23·29	22·41
N_3	42	7·14	
O_6	96		
	588		

Compounds with metals.

Lime water yields a precipitate in an alcoholic solution of biliverdine, which does, however, not appear to be a compound in atomic proportions but a mixture of such a one with excess of free biliverdine.

Lead acetate produces a precipitate in the alcoholic solution of biliverdine, which is more soluble in hot than cold alcohol. Basic lead acetate produces a voluminous precipitate, which is so complete that the fluid has the merest green tinge. Acetate of mercury also produces a precipitate more soluble in hot than cold alcohol. Acetate of copper produces a brownish green precipitate, and the filtrate is nearly colourless. The precipitates of lead, mercury, and copper can be washed with water without dissolving. Freshly precipitated silver-oxyde does not combine with biliverdine without change, but produces oxydation. The derivate is yellow, and soluble in water and alcohol.

In an experiment instituted to measure the quantity of oxygen necessary for the transformation of a given quantity of bilirubine into biliverdine, by means of the deoxydation of an alkaline copper solution, several copper compounds were produced, of which two contained the copper in such a form that it could not be removed by carbonated soda, but followed the product into the alcoholic solution. One of these products had a peculiar spectrum, and exhibited an absorption band in blue when viewed by the aid of Drummond's light.

Spectral Phenomena of some of the Colouring Matters of diseased Bile, and of certain artificial Products.

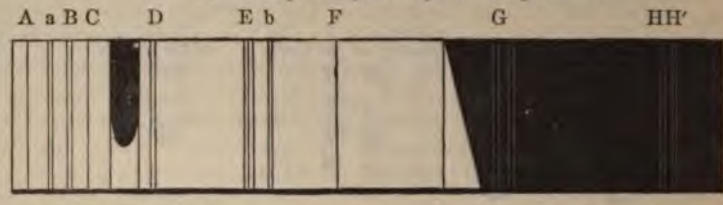
Spectral phenomena of coloured biliary matters.

The normal colouring matters of bile do not yield any particular phenomena of absorption. The spectrum of biliverdine shows red very brilliant and green very prominent, as if the one half of the spectrum was overcast green, the other red. Up to the time of my researches on cholera no derivates of these matters yielding particular *i.e.* characteristic spectra were known. In the report of these researches, p. 496, I gave the first spectra of derivates ever met with. I state again their main phenomena in this place in order the better to be able to appreciate their differences from the newly discovered spectra of pathological colouring matters to be described immediately afterwards.

Cholocyanine.

Cholocyanine.—An ammoniacal solution of cholophæine was treated with concentrated nitric acid until a blue precipitate was formed. This was quickly isolated by filtration, and after washing with water dissolved in alcohol. It showed an absorption band in yellow, which at medium intensity measured 142° 6′—141° 48′=0° 18′. The red was shortened, the green was somewhat obscured; the first half of the blue was clear, but the second half and the rest of the spectrum entirely obscured. See Plate II. fig. 7.

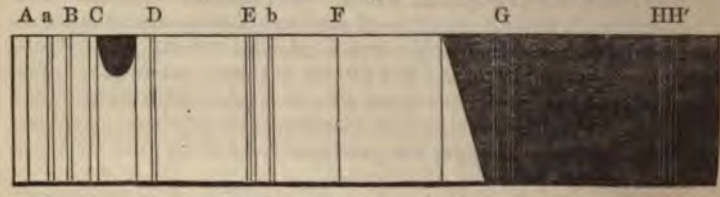
Intensity Diagram of Cholocyanine.



Sulphate of Cholocyanine.

A sulphate of cholocyanine could also be obtained by the action of fuming sulphuric acid and subsequently water upon cholophæine, together with various other green products insoluble in water. The very dilute watery solution showed spectrum, band from 142° 12′ to 141° 48′, very feeble; yellow obscured, red dimmed, green lively, blue only one half its ordinary length, rest obscured.

Sulphate of Cholocyanine dissolved in water.

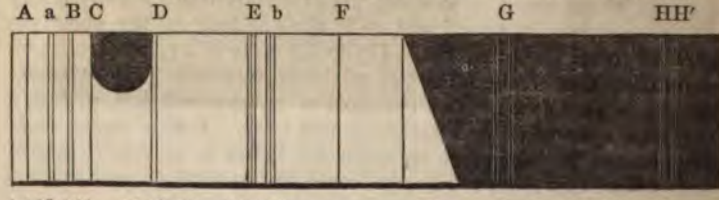


This spectrum of sulphate of cholocyanine by sulphuric acid differs from the one by nitric acid only in this, that the terminal of the band on the red side is 0° 6′ more advanced towards red than that of cholocyanine by nitric acid, while the line nearest to yellow remains the same in both preparations. This spectrum is represented in fig. 8 of Plate II.

Sulphate of sulpho-cholocyanine.

Sulphate of Sulpho-cholocyanine.—Cholophæine was treated with 15 times its weight of sulphuric acid hydrate. After standing six hours it had assumed a reddish green black colour. Diluted with sulphuric acid it was almost impenetrable to light. More diluted red, then a dark band, then some light, but no green, blue, or violet was seen. More diluted there appeared (see fig. 9, Plate II.) red, then band

Intensity Diagram of Sulphate of Sulpho-Cholocyanine.



142° 18′—141° 36—0° 42′, green and blue. This band in the concentrated acid solution is broader in both directions than the band of sulphate of cholocyanine in dilute watery solution prepared by fuming sulphuric acid. The line 141° 36′ was difficult to read, and therefore somewhat doubtful. A second reading of dilute solution gave 142° 6′—141° 36′. A third observation of the spectrum of the concentrated solution between two glass plates, so that a very thin layer only had to be traversed by the light, gave 142° 18′—141° 24′, blue and violet being cut off.

Cholothalline.—The concentrated solution just described on dilution with much water deposits a green precipitate, of which a portion is insoluble, another soluble in acohol. The insoluble portion, cholothalline, has the composition $C_9 H_{11} N O_3$, and is therefore hydrated cholophæine, an isomer of tyroine. The soluble portion has in solution a red colour, and shows two remarkable bands of absorption, resembling somewhat to the bands of blood, but being situated in different parts of the spectrum, *i.e.* more towards the red end than those of blood. This spectrum is represented in fig. 10, Plate II. Cholothalline.

Intensity Diagram of Spectrum of soluble Cholothalline.

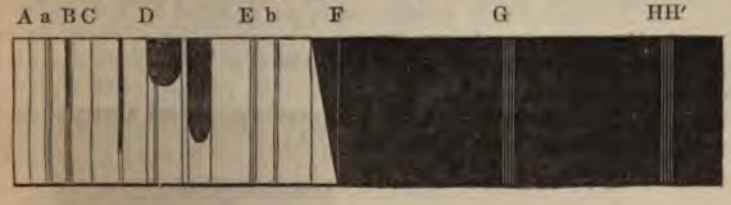
Band.	Measurement.	Width.	Intensity.	Rank.
1.	142° 18′—141° 54′	= 0° 24′	3	= α
2.	141° 48′—141° 6′	= 0° 42′	3	= β

The green ends in faintest bluish black, and the spectrum altogether at 140° 54′.

The foregoing bodies were artificial derivates of cholophæine by chemical processes. The following substances, however, are natural products of diseased processes.

Cholonematine.—The residue (B. II.) from alcoholic extract of colouring matter from human gallstones was dissolved in ether. The solution appeared green in reflected light, brown in transparent dilute solution. The latter showed a remarkable spectrum of four bands. Of these two were thread-like (hence the name), thin, like sunlines; two broader ones were in green and blue. (See Plate IV. fig. 4.) Cholonematine.

Diagram of Spectrum of Cholonematine.



Band.	Measurement.	Width.	Intensity.	Rank.
1	on 35		5	= δ
2	„ 51		8	= α
3	„ 59 to 68	= 9	3	= β
4	„ 70 to 77	= 7	7	= γ

Green shaded from 87; cut off at 106. The fine lines are clearly visible with the sulphide of carbon prism only, but are fused together when seen in the magnifying spectroscope with flint-glass prisms. In the latter red extends apparently uniformly to 51, or α, and is there suddenly cut off. Blue is cut off entirely, even in very dilute solution. The four bands

remain to the end, 1 becoming feeblest is therefore δ. Addition of sulphuric acid makes δ and α very feeble. The spectrum has some similarity to that of xanthophyll (from chlorophyll of grass). But the band in red of xanthophyll is one, and certainly α, while the two bands in green are very feeble. The alcoholic solution of ether extract of bilifuscine from human gallstones before precipitation with ether, on comparison showed no bands. Most similar to cholonematine is the spectrum of fluopittine, described in another part of this report. But in this latter the wider of the two thread-like lines, α, is situated towards the red end, and the thinnest one inside of it, the reverse being the case in cholonematine.

Green colouring matter from ox gallstones. Boviprasine.

Boviprasine, a green colouring Matter from Gallstones of Ox.—The alcoholic extraction of the gallstones left on evaporation a resinous residue which dissolved in ether was submitted to spectral analysis. It showed three bands.

Band.	Measurement.	Width.	Intensity.	Rank.
1 in red	142° 24′ — 142° 6′ = 0° 18′		10	α
2 in yellow	142° — 141° 48′ = 0° 12′		3	β
3 in green	141° 42′ — 141° 24′ = 0° 18′		3	γ

Intensity Diagram of Spectrum of Boviprasine.

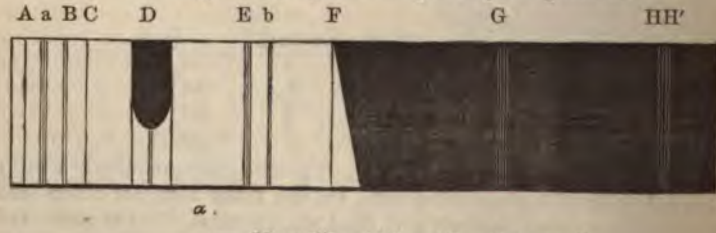
Green cut off at 140° 18′. Seen in the non-magnifying spectroscope, β is divided, a phenomenon not caused by the interference of the sodium line, as this latter is on the green side of the band β.

Compare with boviprasine the spectrum of cellular algæ from pond in Surrey Gardens.

Bovifuscopittine.

Bovifuscopittine.—This resin was extracted from ox gallstones by alcohol. It was treated with caustic potash, precipitated by hydrochloric acid, and dissolved in ether. It did not crystallise. Fatty acids were then removed by precipitation with lime, and the resin was dissolved in alcohol. The solution was brownish yellow to red, without any green tinge whatsoever. In the spectrum it presented a single band overlying the D line. (See Plate IV. fig. 5.)

Diagram of Spectrum of Bovifuscopittine.

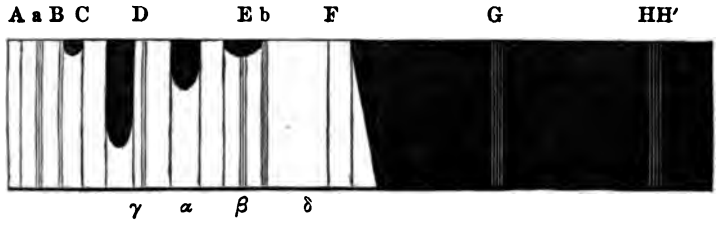


α = 55 to 67 width=12. Intens. 6.

Cut off at 115.

Muscoprasine.—This resin is extracted from ox gallstones by means of alcohol. It has a green colour in the solid state, and retains it on solution in alcohol. In the spectrum it shows bands of great beauty, one in red being very black. (See Plate IV. fig. 6.) The resin has a particular musk flavour. Muscoprasine.

Diagram of Spectrum of Muscoprasine.

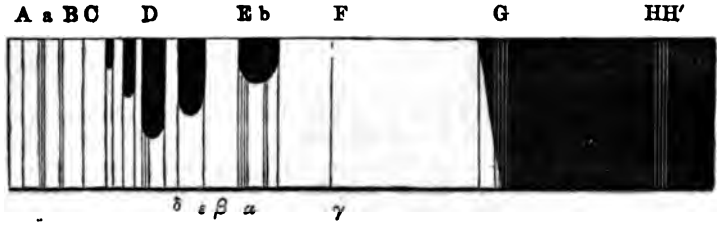


Band.	Measurement.	Width.	Intensity.	Rank.
1.	37 to 42	= 5	1	= γ
2.	50 „ 58	= 8	7	= α
3.	68 „ 77	= 9	3	= β
4.	84 „ 95	= 11	1	= δ

Cut off at 122. 1 and 4 are very feeble bands and difficult to read.

Ethochlorine.—The first ether extraction of ox gallstones yielded a green-coloured substance, which in its second ethereal solution showed the following spectrum (see Plate IV. fig. 7):— Ethochlorine.

Diagram of Spectrum of Ethochlorine.



Band.	Measurement.	Width.	Intensity.	Rank.
1.	48 to 50	= 2	2	δ
2.	54 „ 58	= 4	4	ε
3.	59 „ 66	= 7	7	β
4.	70 „ 77	= 7	5	α
5.	88 „ 100	= 12	8	γ

Violet to 160. In the flint-glass prism and magnifying spectroscope the band 1 is hardly seen. Red reaches to 48, and is then suddenly cut off, but it also reaches to 58, and is then cut off a second time. The margin of the band 1 towards yellow, and that of the band 2 towards the red end, are apparently washed away. This is the most complicated spectrum met with amongst biliary matters, and should be compared to that of cruentine.

Of other coloured ingredients of bile and gallstones, bilifuscine and biliprasine have been chemically examined in various directions, and their elements quantitatively determined. An account of these researches must be reserved until after their completion. Other coloured ingredients of bile.

Bile.—The remarkable reaction of bile known as Pettenkofer's test has been subjected to a special study, which was thought to be of greater importance, when it was found that cerebric acid yielded the reaction just as well as bile acid.

The products separated at present are :—

(*a.*) Precipitate by absolute ether from absolute alcohol solution. (Salts containing five per cent. of S.)

(*b.*) Do. second precipitate, containing acid soluble in water, giving insoluble barium salt.

Acid, precipitated by hydrochloric acid, giving soluble barium salt.

(*c.*) Salts soluble in mixture of ether and alcohol, yielding oleic acid.

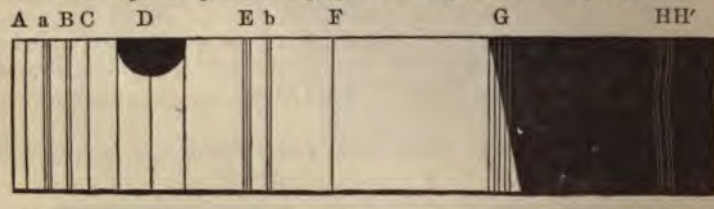
Biliary acid, the essence of reactive power.

Spectrum of bile-test.

The spectrum of the test, which has a peculiar absorption, was determined.

To obtain a very clear solution, acid was employed which had served for producing the test once before. Red slightly shortened. Absorption band in yellow. $142° - 141° 24' = 0° 36'$. (See Plate IV. fig. 8.)

Diagram of Intensity of Pettenkofer's Test Spectrum.



The fluid was prepared by adding a few drops of a concentrated test to a greater bulk of concentrated sulphuric acid until the band could be seen. Another reading gave $142° 6' - 141° 18' = 0° 48'$. Green much dulled. Blue dulled, but not cut off before its ordinary end. This spectrum has to be studied with Drummond's light, as the colour of the fluid is so intense that a very dilute solution obscures the other parts of the spectrum before the band is quite dark enough to show distinct edges. The band given by cerebric acid in Pettenkofer's test is apparently different. It shows $141° 30' - 141° = 0° 30'$. But this also has to be examined in Drummond's light. It is questionable whether the band of cerebric acid in the purple test is due to the purple, as cerebric acid and lecithine from eggs with sulphuric acid alone yield a brown fluid, which red in dilution, shows a very similar band.

Effect of these researches.

The communication of the extremely intricate details of this difficult research must be reserved for another opportunity.

The researches on cholophæine and biliverdine have determined a series of questions with which most animal chemists have for 30 or 40 years been engaged. The chemistry of the bile in its great features has been thereby completed. The chemistry of diseases in which the bile shows abnormal phenomena has been thereby made more easy. The research on cholera furnishes some evidence of this ; in many biles the colouring matters could be diagnosed as well as the biliary acid, and to the absence of either a due consideration could be given.

Influence on current theories.

Of the influence of these researches on current theories one may be mentioned. The hypothesis that the coloured ingredients of bile were

directly derived from those of the blood has been shown to be devoid of any foundation, particularly the erroneous statement that the cholophæine and biliverdine contained *iron* (Harley) has been completely disproved.

Of incidental researches and operations I must mention—

Analysis of a particular brown human gallstone.

Analysis of mixed human gallstones.

Analysis of a specimen of reputed bile colouring matter from man.

Incidental researches and operations.

Operations for extracting colouring matter from ox bile had to be suspended on account of the danger of a nuisance in the neighbourhood of the laboratory.

Ox bile created difficulties.

Extraction of colouring matter from jaundiced urine.

Much essential analysis does not appear.

Many inquiries do not appear in the account, as though they were essential as means for arriving at the truth, they only served to expose previous errors. It is, however, necessary to allude to them in a responsible account, as they include a great number of elementary analyses, which at an early period of the research were the only available tests for the purity of bilirubine and biliverdine, and took up a great amount of time unavoidably, and happily with a positive ultimate result.

Examination of a Gallstone from a Pig.

Gallstone from a pig.

I subjoin here, as of much interest in relation to some of the matters under discussion, the details of my examination of a large gallstone found in a pig.

The gallstone filled the entire gall-bladder ; it was arranged in concentric layers of light and dark yellow colour. The whole was brittle and fell into fragments on removal. It was powdered. The powder was yellow.

Moisture.

Determination of the Hygroscopic Moisture.—The entire quantity of powder, including the hygroscopic moisture, weighed 17·4 grammes. A quantity of this heated at 120° C. until its weight remained stationary lost 8·28 per cent. of water.

Water extract.

Extraction with Water.—The extraction was repeated to exhaustion, and the filtrates, which were very pale yellow, were condensed. A resinous matter deposited. This was redissolved, refiltered, and the solution treated with sodium sulphate to precipitate hyocholate of sodium. A small quantity of this salt, perfectly colourless and of characteristic properties, was isolated in this manner.

Alcohol extract.

Treatment of Powder with Alcohol.—The washed powder was treated with a large volume of alcohol in the cold. After three days' standing large masses of white crystals were found to have been formed. They were fine needles in stellar groups as seen under the microscope. On boiling they dissolved in the alcohol. The powder was therefore exhausted with this solvent, and all the filtrates were united. After evaporation of the alcohol a quantity of nearly white lime-salt was left, weighing 12·06 grammes. This was repeatedly redissolved and recrystallized from alcohol, and the white portions obtained were subjected to analysis. Heated with potassium it yielded no prussian blue, and was consequently free from nitrogen. On combustion with sodium carbonate, and nitre, no sulphuric acid was obtained, consequently sulphur was absent.

Elementary analyses.

Elementary Analyses of the Salt :—

(1.) 0·328 burned and weighed gave 0·025 calcium carbonate, equal to 0·0143 grammes, or 4·35 per cent. Ca.

(2.) 0·346 grammes burned and treated with $H_2 SO_4$ gave 0·0169 gypsum, equal to 4·8 per cent. Ca.

(3.) 0·1995 grammes burned in lead chromate gave 0·0195 H and 0·1309 C, equal to 65·6 per cent. C and 9·7 per cent. H.

These analyses lead to the formula of cholate of calcium. This is singular, as one should have expected to find the hyocholate, which contains more carbon than the cholate. Some other crystallizations yielded products, which on analysis corresponded to the hyocholate of calcium; one product even by its high amount of hydrogen ($C_{24}H_{48}O_8$) was shown to be a new acid, to which I attribute the name of hyocerosinic acid.

Cholate, hyocholate, and hyocerosinate of calcium.

Part insoluble in Alcohol.—This dried on the filter weighed 3·8 grammes. It was treated with dilute hydrochloric acid, and the gases which were evolved, were passed first through an acid solution of arsenious acid, and then through an alkaline solution of barium salt. The former remained clear, so that the absence of any hydrothion (always present in ox gallstones) was proved. The latter gave a precipitate of barium carbonate. The insoluble part was now separated from the hydrochloric acid solution, and the latter was evaporated to dryness on the water-bath. On resolution in little water and a drop of hydrochloric acid, there remained a residue of mucus and a little alumina. The filtrate gave no precipitate or other reaction with hydrothion. On addition of ammonia an immediate precipitate ensued which was soluble in caustic potash, and re-precipitated by very concentrated hydrochloric acid. It was consequently alumina. The tests for phosphoric acid and iron gave no result. The matters which were soluble in ammonia fell on addition of ammonium carbonate and chloride. The precipitate redissolved in hydrochloric acid gave with sulphuric acid a precipitate of gypsum. Barium or strontium were not present. The matters soluble in ammonium carbonate gave a precipitate with ammonium phosphate containing the magnesia. The filtrate evaporated to dryness and ignited with alcohol showed traces ofpotash.

Carbonic acid.

Alumina.

Lime.

Magnesia.

Potash.

The part insoluble in hydrochloric acid was put into a flask and exhausted with hot alcohol. It had assumed a different structure. The original light yellow granules had become disintegrated and passing into a brownish colour. They were dried in the steam-closet, and treated with chloroform. A pale yellow solution was obtained which contained very little material, and on distillation of the chloroform left a green solution, in which even on great concentration, no deposit formed. The solution was further examined as follows:—

Colouring matter.

Chloroform extract.

Green Chloroform Extract.—A large quantity of chloroform boiled with the residue from hog's gallstone assumed a pale yellow colour. After evaporation to a small bulk this solution was of a bright emerald green. In the spectroscope red was cut off at 43, green at 105, and the visible spectrum was all green, yellow and orange being completely overlaid.

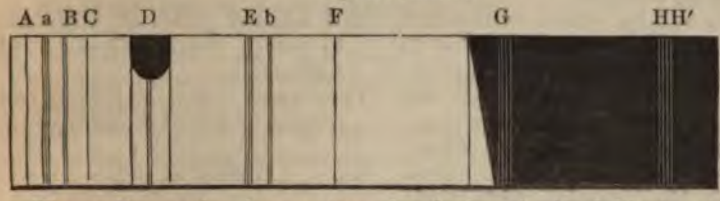
The green solution, shaken with water made alkaline by a drop of caustic potash, yielded all its colouring matter to the water. The alkaline water-solution was purely yellow.

The chloroform solution evaporated left a slight greenish residue, which with nitrous nitric acid gave a purple red reaction, with admixture of blue. The final reaction was not yellow, but colourless.

The watery alkaline solution extracted from the chloroform, after boiling treated with H Cl became blue.

Chemical Characters of the particular Colouring Matter.—Dissolved in alcohol and caustic potash, it forms an intensely yellow solution. This after some standing gives a green precipitate by H Cl. After evaporation of alcohol a yellow matter separates, a blue one remains dissolved. This has a spectrum with a band measuring 55 to 67 = 12. Intens. 3. Yellow to dark green. Blue commences at 106 and reaches to 155. Possibly the band in red extends by a very feeble shade to 81, or even to 88.

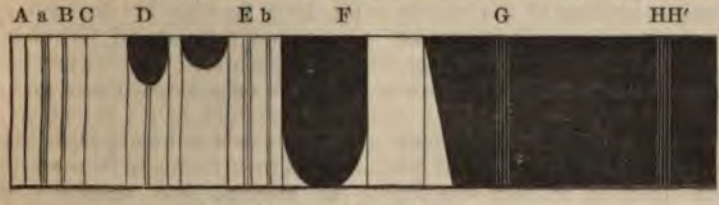
Diagram of Spectrum of Alcohol Solution of Blue Matter or Hyocoeruline.



The yellow colouring matter, hyoflavine, is insoluble in alcohol. Easily soluble in caustic alkali, with a yellow colour. Little soluble in chloroform, with a yellow, after evaporation green, colour. Insoluble in ether, but somewhat soluble in ether and glacial acetic acid.

Nitric Acid Reaction of the Coloring Matter.—This coloring matter was dissolved in alcohol and potash, boiled, and nitric acid added. Red, violet, blue, and green produced from below upwards. The blue solution in spectrum showed three bands. Nitric acid reaction

Diagram of Spectrum of Nitric Acid Product from Hyoflavine.



1	54	— 66	= 12	Intens.	3
2	70	— 84	= 14	„	2
3	101	— 126	= 25	„	10

Blue till 142.

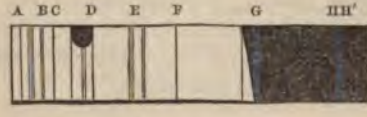
Second band is not completely separated from the first. The green which is free, is broad and beautiful. The solution became on standing more purple, but the bands in spectrum remained the same.

Reaction of Coloring Matter with fuming H_2SO_4.—Green produced, light and beautiful. Diluted with H_2SO_4 solution cuts off end of spectrum to 45. All is green to 110. Blue to 149. No particular bands are discernible. On dilution with water the green colour remains in solution. This test seems to differ from the analogous bilirubine test in this, that the green is of a lighter tint, and that its sulphuric acid solution gives no bands in the spectrum, while cholothalline has two bands. Fuming sulphuric acid reaction.

Comparison of the principal Reactions of

	Hyoflavine.	*Bilirubine.*
	Very little soluble in chloroform, with a yellow colour, becoming green on evaporation.	Comparatively easily soluble in chloroform, with a dark red colour; dilute also yellow.
	Yellow deposit on evaporation to dryness.	Yellow and red deposit on evaporation.
	Spectrum all green, yellow and orange overlaid.	
Reaction of chloroform solution.	Green solution shaken with potash water yields all hyoflavine to water. Light yellow solution.	Red solution yields all bilirubine to potash water. Orange red solution.
	The water solution boiled and treated with acid becomes blue.	The water solution boiled and treated with acid becomes green.
	Slight greenish residue of chloroform solution yields a purple and blue reaction with nitric acid. No yellow at end.	Do. Yellow at end.
	Hyoflavine dissolves in alcohol and potash with an intensely yellow colour. On heating it becomes greenish.	Dissolves in alcoholic potash with orange yellow colour, on heating becomes green.
	From heated solution H Cl precipitates a green matter, which consists of a yellow precipitate, unchanged hyoflavine, and a blue matter, hyocoeruline.	From heated solution H Cl precipitates a yellow-orange matter, which is stained *bilirubine*, and a green matter, *biliverdine*, remains in solution.
	By longer heating of the watery alkaline solution all hyoflavine is transformed into hyocoeruline, which falls at once with acids as a blue matter.	By long heating of the watery alkaline solution all bilirubine is transformed into biliverdine, which falls at once as a green matter.
	By nitric acid red, purple, blue and green reaction produced. Blue alcoholic solution has the following spectrum:	By nitric acid red and purple, blue and green reaction. Blue matter in alcohol has spectrum of cholocyanine, here represented.

Hyocoeruline.	*Biliverdine.*
Blue in alcohol solution.	Green in alcohol solution.
Spectrum: One band in red, situated as in the folowing spectrum.	Spectrum: No band at all.
	Red and green divide the spectrum between them.



Cholothalline.

Spectrum: Two bands in green, similar to blood bands.

Green produced by H_2SO_4.

Spectrum: No bands in sulphuric acid solution.

VII.—COLOURING MATTERS OF THE URINE.

I found it requisite to undertake an "experimental comparison of various modes of determining the quantity of uric acid in urine." The motives for this research are contained in the paper, to be published elsewhere, and arise out of the necessity to begin the study of the dyscrasias (gout particularly) by means of the best methods only, so that results cannot be called in question upon the basis of the science as it was at the time the research was undertaken.

Uric acid, determination of quantity.

The result of the research is the gain of a much improved method of analysis of uric acid in urine, which, while confirming a part of Lehmann's prescription, is an independent improvement of it and of kindred proceedings.

Improved method.

32 days material to be used for determining urochrome.

The physiological part of the research, extending over 32 days, involved the collection, without loss, of the urine excreted during that time. The uric acid having been determined, there remained valuable material in the shape of the extract of over 40,000 C.C. of urine, which it is intended to use for an attempt to determine the amount of urochrome or colouring matter contained in the urine by the amount of the peculiar products of decomposition of that substance (uromelanine, uropittine, omicholine) obtainable under the influence of acids. This will be carried out as soon as the elementary composition and atomic weights of the two last substances are determined as certainly as that of uromelanine.

Uric acid for chemolytic research.

Uric Acid.—About 12 pounds of urate of ammonium were operated upon, and the uric acid (nearly 5 lbs.) obtained in a pure state. The product is intended to serve for a research on uric acid, particularly those products of its decomposition which like alloxan appear to take a share in important chemical pathological processes.

Para-uric acid.

Para-uric Acid.—In the course of the analyses of a case of malignant jaundice or yellow atrophy of the liver I met with a particular form of uric acid, which crystallised in long silky needles. It was more soluble in water than uric acid, and deposited from it on addition of hydrochloric acid. Like para-benzoic acid it gradually changed into ordinary acid while being repeatedly recrystallised.

New alkaloid in human urine.

New Alkaloid in Human Urine.—The search for an alkaloid in tetanus necessitated a parallel examination of healthy human structures and fluids, of which that concerning the urine has resulted in the discovery of a new organic alkaloid. The several processes for the separation of alkaloids, from animal tissues were at the same time subjected to a scrutiny. It remains to be seen in what relation this alkaloid stands to omicholine, a remarkable substance lately extracted from urine, and the analysis of which is not yet completed.

Urochrome products from putrid urine.

Urochrome.—The researches on the coloured ingredients of the urine were continued upon 60 quarts of putrid urine. A quantity of all the usual decomposition products, fixed and volatile, were extracted, but uromelanine alone could be advanced to final analysis, as stated in the essay on that body. During the summer of 1866, some six gallons of fresh urine from healthy adult male persons living regularly were evaporated daily, and after having undergone the several processes formerly described by me, the extracts were treated for the decomposition products which it was desired to obtain.

Preparation of Uromelanine from Putrid Urine. — Pure human normal urine is put into a sulphuric acid flask, or carboy, and allowed to

Uromelanine from putrid urine.

decompose during 12 months. During this time the bottle is kept well stoppered. The clear fermented urine is then drawn off with a syphon, and without filtration immediately evaporated on the steam-bath. During evaporation the formerly clear and yellow urine assumes a dark brown nearly black colour. The concentrated liquid can scarcely be filtered. It is at once treated with sulphuric acid in the cold, which precipitates uromelanine, uropittine, omicholine, and much benzoic acid. The precipitate collected on a filter is exhausted first with boiling water, which removes benzoic acid and other soluble matters; next with boiling alcohol, which takes up uropittine and omicholine. There remains impure uromelanine as a black powder. This is now dissolved in a little caustic potash and much water, and filtered. This process of filtration constitutes the greatest difficulty of the operation, as the mucus suspended in the fluid quickly obstructs the filters. It is therefore necessary to dilute the fluid very much, to let the mucus settle in high beakers, and to filter only the upper clear layers, to the exclusion of the lowest ones. Every filter which becomes clogged should be immediately replaced by a fresh one. The solutions should be allowed to stand, and be refiltered so often that ultimately they will pass easily and without residue through fresh filters. To the clear dark red, in reflected light black solution, sulphuric acid is now added, until the uromelanine falls in flakes and the fluid has an acid reaction. The liquor, after the bulky precipitate has settled, is drawn off by means of the syphon, and washing effected by water and subsequent decantation. Finally the precipitate is stirred up five or six times with strong alcohol, and the alcohol drawn off by the syphon as many times. Ultimately the purple black matter is collected on a filter, washed with alcohol, and dried.

Properties of uromelanine from putrid urine.

The properties of uromelanine thus obtained are identical with those of uromelanine from fresh urine. In particular it is insoluble in water; very little soluble in alcohol, but imparts to this agent a dark red colour, in the cold while it is in its bulky condition, but when contracted and pulverulent boiling is necessary to colour the alcohol. It is very easily soluble in dilute caustic alkalies, ammonia and potash, and precipitated by any acid. From its solution in the smallest quantity of ammonia it is completely precipitated by most soluble salts of the earths and metals. The ammoniacal solution of nitrate of silver produces no precipitate in the ammonia solution of uromelanine, but the precipitate appears on the addition of acetic acid.

Properties of uromelanine in general.

Uromelanine, whether prepared from fresh or putrid urine, is soluble in acetic acid, more in hot than in cold; and from this solution nitrate of mercury precipitates a red matter. On dry distillation it gives out white fumes, which condense to an oil, but no sublimate of any kind is obtained. The fumes or oil are neutral, bleaching rather than changing, like acid or alkali, the colour of litmus. They give no aniline reaction, but with nitrate of mercury they give an exquisite red reaction and precipitate. A very voluminous dense charcoal of the bulk of the original particles remains.

Uromelanine dissolves in nitric acid with a dark red brown colour. Red vapours are evolved on boiling, but the reaction is not violent even with much acid. After long boiling the solution is yellowish red. Addition of water produces a fawn precipitate which is entirely soluble in alcohol, and with ammonia and barium chloride gives a voluminous yellow precipitate. When the nitric acid is evaporated two matters are left, one soluble in alcohol the other insoluble. The solution gives the red reaction with nitrate of mercury.

Concentrated fuming sulphuric acid easily dissolves uromelanine, forming a red or purple solution. Immediate addition of water preci-

pitates all coloured matter, and the liquid is white and clear. But when the concentrated mixture is allowed to stand over night, water precipitates a coloured portion; another coloured portion remains dissolved. Carbonate of barium precipitates all coloured matter on boiling, and the filtrate is again white.

Recently precipitated uromelanine suspended in water and subjected to the action of chlorine yields a brownish substance, soluble in boiling alcohol. While the spirit is being heated, some of the substance melts to a brown resin, which dissolves by continued heating with new alcohol. The solutions added together yield on cooling yellowish red amorphous flakes. These flakes are not again entirely soluble in alcohol, probably because the chloro-compound undergoes a change during the heating with the alcohol and subsequently. This supposition was confirmed by the results of elementary analysis.

List of Preparations of Uromelanine referred to in this Research.

List of preparations.

1. *Prize Essay Preparations.*

From fresh urine.	By boiling with H_2SO_4	A. I.	Element. analyses, neutral barium salt; zinc salt; lead salt.
		A. II.	Silver salt; barium salt.
From putrid urine.	By addition of H_2SO_4, no boiling.	A. III.	Silver salt; barium salt; calcium salt.

2. *Preparations made specially for the present Research.*

From fresh urine.	By boiling with H_2SO_4	B. I. B. II. B. III.	2 Elementary analyses.
	Before boiling	C. I.	
	After boiling with H_2SO_4	C. II.	6 Elementary analyses.
	Before boiling	D. I.	2 Elementary analyses. Silver salt.
	After boiling with H_2SO_4	D. II.	Calcium salt; zinc salt.
		D. III.	
		D. IV.	2 Elementary analyses. Silver salt; barium salt; zinc salt.

From the notes on the left it will be seen that uromelanine from putrid urine, A. III., and C. I. and D. I. from fresh, were obtained without boiling, by the mere addition of acid to the concentrated liquid. All the other specimens required boiling of the mixture for their formation. The notes to the right of the numbers indicate the analyses and combinations to which they were subjected.

Synopsis of Uromelanates produced for this Research.

Synopsis of uromelanates.

Silver Salts.

Ur.	:	Ag.	Ag. found.	Preparation employed.
1	:	1	13·38 per cent.	A. II., A. III.
2	:	3	18·56 „	D. I.
3	:	5	20·45 „	D. IV.

Barium Salts.

Ur.	:	Ba	Ba found.	
5	:	2	7·20 per cent.	D. IV.
2	:	1	9·05 „	A. I., D. IV.
4	:	3	13·28 „	A. II., A. III.

ENDIX.

Calcium Salts.

Ũr.	:	C	Ca found.	
5	:	2	2·03 per cent.	D. I.
4	:	3	4·35 „	A. III.
2	:	3	7·27 „	D. I.

Zinc Salts.

Ũr.	:	Zn	Zn found.	
3	:	1	2·82 per cent.	D. I.
5	:	2	3·54 „	A. I.
2	:	1	4·42 „	D. IV.

Lead Salt.

Ũr.	:	Pb	l.	
3	:	2	cent.	A. I.

Elementary Composition of Uromelanine.—From the analyses of preparations A. I., A. IV. (leaving C. II. at present out of the calculation the two-thirds basic silver salt Ũr : Ag = 3 : 5, it elanine is $C_{36}H_{43}N_7O_{10}$.

		Theory of	ents.	Found mean.
C_{36}			93	57·21
H_{43}			86	5·74
N_7			86	12·88
O_{10}	160		85	24·17
	733	1	00	100·00

Silver-compound. (Ũr Ag.)

Normal or neutral Uromelanine-silver.—Ũr : Ag = 1 : 1. A neutral ammoniacal solution of uromelanine was prepared by evaporating a dilute solution of the substance in ammonia water to dryness on the water-bath, and extracting the salt which had remained soluble from the uromelanine which had become insoluble by the loss of ammonia by means of water. This dark brown solution was precipitated by silver nitrate, the precipitate contracted by heating in the fluid, washed by decantation, then on the filter, and dried in the steam-closet. The compound had the composition expressed by the formula $C_{36}H_{40}AgN_7O_9$; it was therefore Ũr + Ag − H_2O, or an atom of water had left upon the substitution of an atom of hydrogen by one of silver.

Theory of atoms.		Per Cents.	Mean found.
C_{36}	432	52·55	52·41
H_{40}	40	4·86	5·15
N_7	98	11·92	12·47
O_9	144		
Ag	108	13·13	13·38
	822		

Silver-salt. ($Ũr_2Ag_3$.)

Half-basic Silver-uromelanate, Ũr : Ag : : 2 : 3.—Uromelanine was dissolved in a minimum of ammonia, and the solution digested with an excess of uromelanine which remained undissolved. The solution was now boiled for a long time; as on cooling a slight deposit ensued the solution was filtered. It was then precipitated with silver nitrate, washed and dried at 100° to 105°. It yielded 18·57 per cent. of Ag,

and contained, therefore, exactly two $\tilde{U}r$ upon three silver. Or it consists of one atom of neutral and one of basic salt.

$$\begin{array}{l} 2 \text{ uromelanine} - 3H = 1{,}463 \\ 3 \text{ silver} \qquad\qquad\quad 324 \\ \hline \qquad\qquad\qquad\quad 1{,}787 \end{array} = \begin{cases} \tilde{U}r + Ag \\ \tilde{U}r + \begin{cases} Ag \\ Ag \end{cases} \end{cases}$$

Silver-compound. ($\tilde{U}r_2\,Ag_3$.)

Two-thirds basic Silver-uromelanate.—$\tilde{U}r : Ag :: 3 : 5$. Some uromelanine was dissolved in concentrated ammonia water, and after having been boiled down to one-half was precipitated with silver-nitrate. The filtrate and first washing water were colourless, but the later washings became progressively darker. These dark filtrates, however, contained no trace of silver. The preparation contained 20·1 per cent. of Ag. It was therefore clear that the ammonia could not be sufficiently removed from a uromelanine solution by boiling down to one-half. A third of the same solution was treated with $\mathfrak{B}a\,Cl_2$, and yielded the neutral barium compound, as if the solution had been strongly alkaline. A second preparation was therefore made as follows: The uromelanine was dissolved in ammonia and the solution was evaporated, not as in the first preparation only to one-half, but to dryness. The residue easily dissolved in water, leaving but an insignificant quantity of insoluble matter behind. This circumstance pointed to the presence of enclosed alkaline salt. The filtered fluid was treated with silver-nitrate, and the flocculent precipitate washed on a filter. The first filtrate was colourless, the subsequent washings slightly coloured. Its analysis led to the following data:—

Pentargyric Triuromelanine.

	Atomic Weights.	Required in 100.	Found mean.
$\mathfrak{C}_{108}$	1,296	47·40	46·90
H_{124}	124	4·53	4·77
Ag_5	540	19·75	19·77
N_{21}	294	10·75	10·36
$\mathfrak{O}_{30}$	480	17·57	18·20
	2,734	100·00	100·00

This result by the following formula $\frac{2{,}734 - 540 + 5}{3} = 733$ leads to the atomic weight of uromelanine as also determined by other analyses. But this silver salt is the firmest basis for that theory, as it is very definite, and has been analysed repeatedly regarding its four directly determinable elements. The means found correspond in a remarkable manner with the requirements of theory.

Barium salt. ($\tilde{U}r_5\,\mathfrak{B}a_2$.)

Half-acid Barium-uromelanate.—$\tilde{U}r : \mathfrak{B}a = 5 : 2$. $\tilde{U}r$ was dissolved in excess of concentrated ammonia, and precipitated by $\mathfrak{B}a\,Cl_2$. It was washed during more than a week with nearly 100 portions of water, before it became steady and the filtrates were free from $\mathfrak{B}a$.

Theory of Atoms		in 100.	Found.
$\mathfrak{C}_{180}$	2,160	54·89	52·96
H_{211}	211	5·36	5·5
N_{35}	490	12·44	11·88
$\mathfrak{O}_{50}$	800		
$\mathfrak{B}a_2$	274	6·96	7·2
	3,935		

Barium salt. ($\tilde{U}r_2$ Ba).

Neutral Barium Uromelanate.—$\tilde{U}$: Ba = 2 : 1. A dilute strongly alkaline solution of uromelanine was treated with barium chloride, the precipitate washed with water and dried. A second preparation was made from the same specimen by boiling its strongly alkaline solution down to one-half, and then precipitating it by $BaCl_2$. During washing the coloured filtrates became darker, and the Ba ceased to be contained in them, before uromelanine. The precipitate was washed with alcohol, dried, and analysed.

	Theory of Atoms	in 100.	Mean found.
C_{72}	864	53·96	„
H_{84}	84	5·24	„
N_{14}	196	12·24	11·3
O_{20}	320	„	„
Ba	137	8·55	8·34
	1,601		

Barium salt. ($\tilde{U}r_4$ Ba_3).

Tribarytic Tetrauromelanine.—$\tilde{U}r$: Ba = 4 : 3. The precipitation of this barium salt has to be effected in a solution containing a minimum of ammonia, otherwise the gelatinous precipitate retains ammonia longer than the excess of chloride of barium, and the alkali then decomposes a small quantity of the combination, so that the filtrates which at first are colourless become darker as the washing proceeds. The first washing is therefore best effected with water containing a little chloride of barium, and ultimately the washing is completed with alcohol. The compound consists of one molecule of basic and one molecule of neutral uromelanate.

$$\left.\begin{array}{l}\tilde{U}r\ Ba\\ \tilde{U}r\ Ba\\ \hline \tilde{U}r\ Ba\\ \tilde{U}r\end{array}\right\} = C_{144}\ H_{166}\ Ba_3\ N_{28}\ O_{40}$$

$$4 \times 733 = 2{,}932 - 6 = 2{,}926$$
$$+ 3\ Ba = 411$$

Molecular weight of compound = 3,337

This theory derives great support from the constitution of a calcium compound to be described lower down.

Calcium salt. ($\tilde{U}r_8$ Ca_2).

Half-acid Calcium-uromelanate.—$\tilde{U}r$: Ca : : 5 : 2. The ammoniacal solution was made neutral by digesting it with excess of uromelanine, and after filtration boiling it, and filtering again from a little deposit which had formed. $\tilde{U}r$ 733 × 5 = 3,665 + 2Ca = 80 − 4H = 3,741 requires 2·13 per cent. Ca, found 2·03 per cent. Ca.

Calcium salt. ($\tilde{U}_4$ Ca_3).

Tricalcic Tetrauromelanine.—$\tilde{U}r$: Ca = 4 : 3. In the preparation of this salt the same precautions have to be observed which have already been mentioned under uromelanine-barium. It has to be washed with water containing chloride of calcium, and ultimately the excess of

hloride has to be removed by alcohol. The compound is exactly nalogous to the tribarytic tetrauromelanine, and its formula is

$$\left.\begin{matrix}\tilde{U}r\\ \tilde{U}r\end{matrix}\right\}\text{Ca}\Bigg]\\ \left.\begin{matrix}\tilde{U}r\\ \tilde{U}r\end{matrix}\right\}\text{Ca}\Bigg] = \text{C}_{144}\,\text{H}_{166}\,\text{Ca}_2\,\text{N}_{28}\,\text{O}_{40} = \text{Mol. W. } 3{,}046.$$

Tricalcic-diuromelanine, or Hyperbasic Calcium-uromelanate.— Calcium salt. $\tilde{U}r : Ca :: 2 : 3$. The strongly alkaline solution was precipitated with $(\tilde{U}r_2Ca_3)$. Ca Cl_2 and dried at 100°.

1,466 — 6 + 120 = 1,580, requires in 100° Ca 7·59, found mean 7·33.

$$\left.\begin{matrix}\tilde{U}r\\ \tilde{U}r\end{matrix}\right\}\begin{matrix}\text{Ca}\\ \text{Ca}\\ \text{Ca}\end{matrix}\Bigg] = \text{C}_{72}\,\text{H}_{80}\,\text{Ca}_3\,\text{N}_{14}\,\text{O}_{20}.$$

Acid Zinc-uromelanate, or Monozinc Triuromelanine.—$\tilde{U}r : Zn :: 3 : 1$. A quantity of $\tilde{U}r$ was dissolved in ammonia and made neutral by boiling for 1½ hours. The vapour then did not give any fumes with the H Cl glass rod. Sulphate of zinc was employed for the precipitation. Analysis yielded 2·82 per cent. Zn, which leads to the following theory :— Zinc-salt. $(\tilde{U}r_3Zn)$.

$$\begin{aligned} 3\,\tilde{U}r - 2\,H &= 2{,}197\\ +1\,Zn &= \quad 65\end{aligned}$$

1 mol. of compound = 2,262 requiring in 100 2·87 per cent. Zn.

$$\left.\begin{matrix}\text{Ur}\\ \tilde{U}r\\ \tilde{U}r\end{matrix}\right\}\text{Zn}\Bigg] = \text{C}_{108}\,\text{H}_{127}\,\text{Zn}\,\text{N}_{21}\,\text{O}_{30}.$$

Normal Zinc-uromelanate.—$\tilde{U}r : Zn :: 2 : 1$. Some uromelanine was dissolved in concentrated ammonia and after having been boiled to drive off the excess of ammonia was precipitated with zinc sulphate. The filtrate and first washing water were colourless, but by progressive washing the water became darker. As these filtrates contained no zinc the washing was arrested and the compound dried. The zinc was determined as oxyde by combustion, and found to amount to 4·42 per cent. Zn. This leads to the formula $C_{72}\,H_{84}\,Zn\,N_{14}\,O_{20}$ M.W. = 1,529. Zinc salt, $(\tilde{U}r_2Zn)$.

The solution employed in this experiment was one-third of a solution, the other third of which yielded the second preparation of normal or neutral barium-uromelanate, which contained 8·03 Ba. The last third of the solution by treatment with silver-nitrate yielded not a normal but a two-thirds basic silver-salt, or pentargyric triuromelanine with 20·11 per cent. of Ag, or a trifle in excess of the theory.

Half-acid Uromelanate of Zinc.—$\tilde{U}r : Zn :: 5 : 2$.—A preparation was made by adding Zi SO_4 to a filtrate from uromelanate of ammonia which during evaporation had lost ammonia, and deposited a portion of its uromelanine in scales. Another preparation was obtained by treating the mother liquors from urochrome preparation with lime, ultimately with Zi Cl_2 to separate creatinine. The creatinine-chloride of Zinc salt, $(\tilde{U}r_5Zn_2)$.

zinc deposit was washed, and then dissolved in boiling water. A gelatinous brown precipitate remained undissolved, and was found to be uromelanine-zinc by analysis. The molecular weight of this salt is $2\,\text{Ẓi} = 130 + 5\,\text{Ur} - 4\,\text{H} = 3{,}661$, total $= 3{,}791$. This requires 3·42 per cent. Ẓn. Found 3·54 per cent.

It may be considered as a compound of two molecules of neutral zinc uromelanate and one molecule of uromelanine. Thus :—

$$\left.\begin{matrix}\tilde{\text{U}}\text{r}\\ \tilde{\text{U}}\text{r}\end{matrix}\right\}\text{Ẓn}\qquad \left.\begin{matrix}\tilde{\text{U}}\text{r}\\ \text{Ur}\\ \tilde{\text{U}}\text{r}\end{matrix}\right\}\text{Zn}\qquad \Bigg\}=\text{one molecule of dizincic penta-uromelanine.}$$

Lead salt, ($\text{Ur}_3\,\text{P̶b}_2$)

Half-basic Uromelanate of Lead.—$\tilde{\text{U}}\text{r} : \text{P̶b} :: 3 : 2$. A solution of uromelanine from fresh urine in ammonia was made, so neutral that some uromelanine remained undissolved. To the clear filtrate neutral acetate of lead was added. The precipitate was perfect, the filtrate colourless. The precipitate was washed until the filtrates were free from lead.

Molecular weight of this compound :—

$$\overbrace{3\,\tilde{\text{U}}\text{r}}\quad -4\,\text{H} + 2\,\text{P̶b}$$

$$733 \times 3 \quad -4 \quad +414 \quad = \quad 2{,}609. \quad \text{M. W.}$$

$$\text{P̶b required in } 100 \quad = \quad 15{\cdot}86.$$

$$\text{found} \quad \text{,,} \quad = \quad 15{\cdot}703.$$

$$\left.\begin{matrix}\text{Ur}\\ \tilde{\text{U}}\text{r}\\ \tilde{\text{U}}\text{r}\end{matrix}\right\}\begin{matrix}\text{,,}\\ \text{P̶b}\\ \text{P̶b}\end{matrix}\Bigg\}=\text{one molecule of diplumbic tri-uromelanine.}$$

The Origin and Physiological and Pathological Significance of Uromelanine.

Uromelanine is not as such contained in urine, but is a product of the decomposition by putrefaction, or the influence of sulphuric acid and time, or sulphuric acid and heat of another substance contained in it. This original substance is urochrome, the colouring matter. When urochrome splits up into its constituents under the influence of putrefaction it does not immediately yield uromelanine, but a less oxydised substance of light yellow colour, which on exposure to oxygen quickly becomes brown ; and during evaporation of the putrid urine, while exposed to air, assumes a perfectly black colour, and is in part precipitated.

It is this melanigenous substance together with the carbonate of ammonia which gave to putrid urine its value in indigo-dyeing ; the ammonia dissolved the indigo, the melanigene reduced it, the textures to be dyed were now steeped, and on subsequent exposure to air assumed the indigo-blue colour. As 300 pounds of good putrid urine were required to dissolve and reduce one pound of indigo, it is possible to form a rough guess of the quantity of melanigene present in that quantity of urine, supposing melanigene to be the only oxydisable substance present in putrid urine.

Uromelanine probably contained in melanotic tumours.

Late researches instituted in the hospital at Prague have made it probable that melanigene or melanine are regular ingredients of melanotic tumours, particularly the cancers of that class. It is true that the "melanine," which the Prague observers extracted from the urine

of patients suffering from melanotic cancer, is nothing else than the uromelanine which can be obtained from all urine. But as they assert to have obtained the same substance from the tumours themselves a remarkable inquiry is opened.

In his analyses of the pigment of the choroidea, Scherer had found results which it is interesting to compare with those yielded by uromelanine.

Melanine of the eye.		Ũr.	Theory of Ũr.
C	58·28	57·21	58·93
H	5·92	5·74	5·86
N	13·77	12·88	13·36
O	22·03		

The composition of melanine is, therefore, very similar to that of Ũr. as found, and more so to that calculated from its compounds.

Rosow, however, at a later period found in the pigment of the choroidea, Heintz in pigment from melanotic tumour—

Pigment of choroidea.		Melanine of tumour.	
C	54·0	C	53·44
H	5·3	H	4·02
N	10·1	N	7·1
O	30·	O	35·44
Ash	0·6		

As Rosow did not analyse a pure preparation, we cannot attribute the same value to his analyses as to those of Scherer.

Uromelanine, why remarkable.

As the most general result of these new researches we make the acquaintance of one of the most interesting and remarkable compounds in the whole range of organic chemistry. The distinction here claimed belongs to uromelanine in the first instance, by reason of its atomic weight, which is 733. There are but very few organic substances which attain so high a number of carbon atoms as 36, and still fewer which combine with that number, besides hydrogen and oxygen, seven atoms of nitrogen. Uromelanine is a very stable body compared to any compound of similar atomic pretensions, and combines readily in a great variety of proportions with very different bases. Its derivates of a substitutive or otherwise metamorphic quality promise to be very great in number, and invite the chemist to attentive study. But by far the greatest interest attaches to uromelanine as an animal matter, and particularly as that animal product which amongst all decomposition products of excretory substances of the animal economy occupies by its atomic weight and complicated constitution the highest place. Another element of the importance claimed for this substance is the circumstance that it affords an imperturbable basis for the operations which animal chemistry will have to undertake in order to determine the nature, composition, and atomic weight of the colouring matter of urine. This latter must necessarily have a higher atomic weight than 733, and possess a constitution of singular complication and variety as regards the nuclei or radicals contained in it. Then if our ideas about the nature of excretory substances are correct in their application to urochrome no less than to uric acid, we are driven to the assumption that as uric acid is a derivate of albumen, so urochrome is a derivate of a constituent of the blood of much higher atomic complication than albumen, and as such we could claim only one material, namely, the most characteristic ingredient of the blood corpuscles, or hematocrystalline, the crystallisable compound which may be split up into an albuminous body and into

Uromelanine firm basis for studying urochrome.

Urochrome possibly derived from cruorine.

hematine. We thus may obtain, probably, a new means of estimating the effects of the febrile process upon the organ of oxygenation, the blood-disk, or its ally, the myochrome or red colouring matter of the muscles. But we also obtain by a direct process of reasoning a new insight into the chemical processes of life altogether. If uromelanine is of atomic weight 733, its precursor urochrome could not be a derivate of albumen with atomic weight 1,612, or of fibrine with atomic weight 2,200, but would have to be derived from a compound of much higher chemical constitution. This could not be hematine, but solely hemato-crystalline, to which we now begin to attribute the importance of being a chemical compound of about 13,000 atomic weight. Hitherto we had been taught that the animal was not a chemical machine with a synthetical tendency of higher aim than the production of fat or wax from sugar and starch. It was believed to receive all its materials, its albumen, caseine, cerebric acid, in a ready-made condition from the plant; no doubt it organized them in the shape of tissues, but it was believed incapable of chemical synthesis of a high order. We shall now have to change these views completely. The highest atomic weight produced in the plant is about 2,200, the highest atomic weight produced in the animal is about 13,000. The complication of the material of the most developed chemical machine of the animal is six times greater than the most complicated material produced in the vegetable economy.

Probable high atomic weight of cruorine.

New philosophy regarding animal synthesis being higher than that of plants.

Paramelanine.

As in spectroscopic analysis of inorganic matters light shoots up here and there for an instant, marking the presence of a minute amount of some matter or other, so in general analysis a few collateral products are met with which indicate their own existence, but at the same time a genetic coherence of the matters under investigation. While uromelanine preserves no reminiscence in its optical characters of the hematine to which it has such particular similarity by its stability and high atomic weight, there is accompanying it a small amount of a substance, which when treated with sulphuric acid yields the spectrum of cruentine.

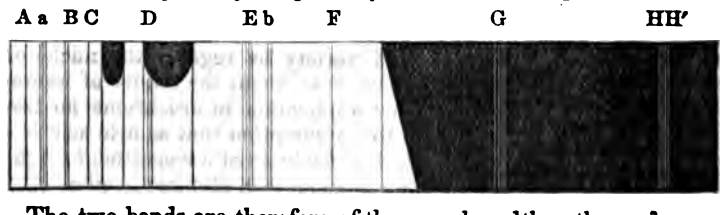
Body accompanying uromelanine yields the spectrum of cruentine.

Paramelanine.

This body I term paramelanine. It was obtained in the following manner. Uromelanine, after separation from the products soluble in alcohol, was dissolved in potash and re-precipitated by sulphuric acid. It was washed with water, lastly with alcohol. These alcoholic solutions had stood a long time and deposited a black matter. This was found to have become insoluble in ammonia. Dissolved in concentrated sulphuric acid it showed a spectrum with two bands.

1. 142 °6′—141° 54′=0° 12′
2. 141° 45′—141° 15′=0° 30′

Diagram of Sulphate of Paramelanine spectrum.



The two bands are therefore of the same breadth as those of cruentine-sulphate, but they are situated 0° 12′ more towards the violet. On addition of water the solution remains clear, and the dilute liquor retains

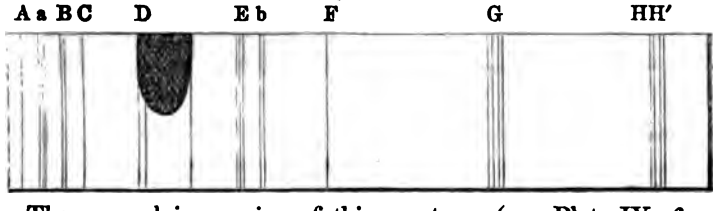
the bands. It has not yet been possible to cause this body to undergo the transformations of cruentine, as its quantity is too small in comparison with the impurities with which it is mixed. What little can be extracted from the original residue by ammonia exhibits no bands.

Omicholine and Omicholic Acid.

Conjointly with uromelanine and paramelanine there are obtained from urine by the chemolytic process other bodies, of which uropittine shows no particular spectral phenomena. The more remarkable are the spectral phenomena of omicholine and omicholic acid.

Omicholine. Omicholine is a part of the resinous product which is soluble in alcohol and ether. It is insoluble in ammonia, and does not combine with bases. It dissolves a little in boiling water. It is exceedingly difficult to obtain it pure. Many analyses of several specimens have led to an average empirical formula C_{52} H_{86} NO_3. It has a powerful odour, most apparent on heating, and when a little only is burned fills the room with the peculiar odour of burned urine. Its solution in ether has a fine ruby red colour, and shows a band in green, 141° 42′ – 141° 12′ = 0° 30′. Near to it in green there is a shading. What ought to be the blue part of the spectrum is strikingly violet. This peculiarity indicates the fluorescent character of the matter which we accordingly discover. In the sun-cone the red solution fluoresces green, thus offering the reverse of the phenomena of chlorophyll, which is green and fluoresces red.

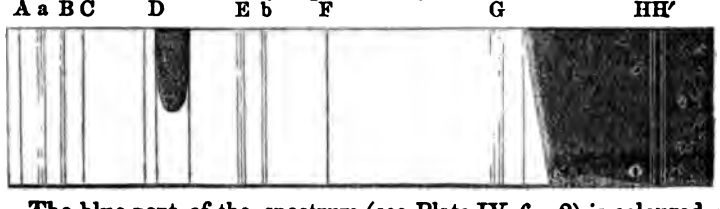
Diagram of Spectrum of Omicholine.



The general impression of this spectrum (see Plate IV. fig. 1) is that it consists of three parts, of which the red and yellow are very light; then follows the green part with the band, and lastly a violet end without any blue.

Omicholic acid. Omicholic acid is that part of the resinous products soluble in alcohol which is soluble in ammonia, and thereby separated from omicholine. It is very similar to omicholine, and one is probably derived from or closely related to the other, although they differ very much in chemical composition. For the average of many analyses of omicholic acid has led to the empirical formula C_{15} H_{23} NO_4. The ether-solution of omicholic acid has a band in green, 141° 36′ – 141° 18′ = 0° 18′

Diagram of Spectrum of Omicholic Acid.



The blue part of the spectrum (see Plate IV. fig. 2) is coloured violet. The entire spectrum makes the impression of being divided into two parts

by the band, one being very light, the other shady and containing only little violet instead of blue. The chloroform solution has the same spectrum, but the second part is almost entirely obscured. The ammoniacal solution of omicholic acid has no bands in the spectrum. Omicholic acid is red, and fluoresces green, but there are slight differences in its phenomena from those of omicholine.

In order to exhibit the differences of the spectra of these substances from those of choleraic urorubine and urocyanine (see Plate III. figs. 2 and 3), I subjoin diagrams of the latter :—

Diagram of Spectrum of Choleraic Urocyanine.

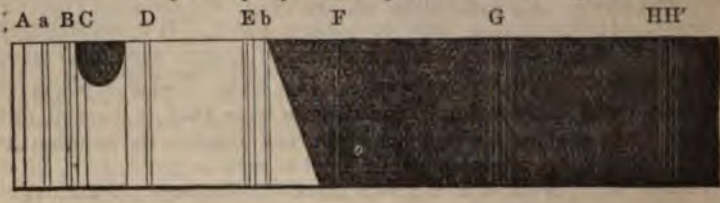
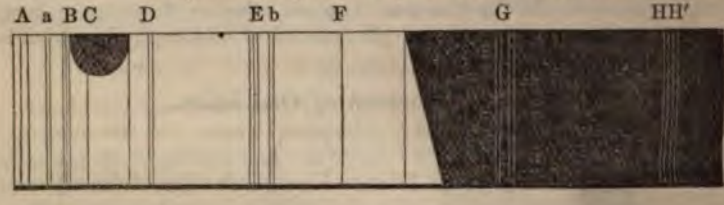


Diagram of Spectrum of Choleraic Urorubine.



Determination of the Quantity of Uromelanine obtainable from healthy Urine.

Quantity of uromelanine in healthy urine.

The whole amount of urine passed by a healthy man in 24 hours, amounting to 2,072 cubic centimetres, was evaporated to a syrupy consistency, and then some dilute sulphuric acid added to it. After 24 hours' standing the precipitate was separated, and found to consist of uric and hippuric acid, coloured brown by a little colouring matter. The filtrate was mixed with a little more sulphuric acid and distilled on the sand-bath. The first portion of distillate had a penetrating odour, and was yellow; over night it became darker. The later distillates were almost colourless, and remained unaltered. The fluid in the retort was filtered from the formed deposit, the latter washed, and extracted with alcohol. What remained insoluble, uromelanine, was dried at 105°, and found to amount to 0·7315 grammes. The alcoholic extract, containing omicholine, omicholic acid, and uropittine after evaporation of the alcohol, amounted to 0·3472 grammes.

This being the first attempt to determine the physiological quantities of the ingredients of urine which yield uromelanine, it would be hazardous to state conclusions. It is remarkable that the quantity of uromelanine obtained from a day's urine is about equal to that of the uric acid excreted on an average under similar conditions.

Uromelanine, &c., in a case of Tropical Fever.

Uromelanine in tropical fever.

A gentleman, a coffee planter from the south of India, was obliged by unceasing attacks of fever to return to England. He arrived

emaciated, with a yellow coloured skin peculiar to the subjects of tropical fever. His tongue was much furred; the liver was so greatly enlarged that the probability of its containing an abscess had been suggested. The urine was of a deep red colour, and deposited urates. The urine from two days was subjected to the chemolytic process described in the foregoing. During boiling of the products in alcohol a small quantity was lost by bumping, the quantities found by weight are therefore only approximatively correct, but can be assumed as such.

Uromelanine found - -	0·2915	grammes.
or per 24 hours - - -	0·14575	„
Uropittine and omicholine -	0·1242	„
or per 24 hours - - -	0·0621	„

The products soluble in alcohol stand therefore to the uromelanine in the same relation of quantity as in the healthy urine. The total quantity of products was certainly less than from healthy urine, although the actual amount, owing to the accidental loss, cannot be accurately stated.

This urine yielded no uric acid whatever, and the filtrate from the uromelanine was unusually dark, as if it contained an abnormal colouring matter in solution.

VIII.—Studies of the Urine in Morbus Addisonii.

A woman, *J. T.*, formerly a servant at the Shorlane workhouse, was admitted into the Middlesex Hospital, under Dr. Sanderson, September 16th, 1867.*

Family history.—Father died of hemorrhoids at the age of 40, mother of diseased heart at 60. One brother met with his death accidentally, another died of some chest affection, and a sister, still living, enjoys good health.

Previous history.—When 14 years of age had typhus. Was born in Scotland, but for the last six years has lived in London, and has been subject to occasional catarrh with cough, but without expectoration. Her patella was once fractured, and she says that three years ago she strained her back while turning a mangle, causing lameness for a time, and being followed by pain in mid-dorsal region, which lasted some two or three months. In July 1866 she fell downstairs, had hemophysis two or three days after, and felt pain in the back for a week or 10 days.

History of present illness.—About a year ago caught cold, which lasted some four months, after which felt weak, drowsy, and languid, symptoms which appear to have been gradually coming on from the time she first took cold, for she states that six weeks after her present illness commenced she had nausea and vomiting which lasted for three months without intercession, but these symptoms were accompanied with, and also preceded by, much languor and drowsiness.

After three months of continuous sickness, two months elapsed, during which patient did not vomit at all, but the general weakness with drowsiness and languor still continued; moreover, gradually increasing palpitation after slight exciting causes was now for the first

* My thanks are due to Dr. Sanderson for kindly having afforded me opportunities of observing this remarkable case, and to Dr. King, resident physician to the Middlesex Hospital for the great care and regularity with which he transmitted to me the daily records of the case, and the specimens of excretions submitted to analysis.

time noticed. The nausea and vomiting then returned, and lasted about seven weeks, during which time there was sickness after food regularly once or twice a day. At this time also she complained of pain in the knees and ankles, but nowhere else.

There followed a period of entire freedom from nausea and vomiting, which lasted till two weeks before her admission, nevertheless she always felt tired and sleepy. Patient gave up work in August 1866, but took another place for a couple of months, which she resigned owing to present illness. She has lately been spending her time at Hammersmith for the benefit of her health. A fortnight ago sickness recommenced, but lasted one day only. There has been some dyspnœa on exertion for the last seven months. Catamenia are regular but scanty and pale. Patient first observed that she was getting darker about three months ago, and some six weeks before that thought she was slightly jaundiced, as there was a yellowish tinge about the face.

State on admission.—Pulse, 84; resp. tranquil; B. confined, stools somewhat hard; mucous membranes of hard palate discoloured and darkened. Skin of face, neck, and hands of a dark olive brown colour; that of trunk and lower extremities discoloured in a less degree; beneath the chin and at the left side of the neck a few morbidly white patches may be observed. No pain or tenderness in hypochondria or loins. Hepatic dulness normal.

Phys. signs.—There is impaired resonance of the right supra scapular fossa. It is also doubtfully defective below either clavicle, where expiratory murmur is somewhat harsh, and heart sounds are abnormally distinct, but no moist râles are audible. At the bases partial resonance extends downwards to level of 11th spina; and in tracing the limit of resonance forwards it is found to extend upwards and forwards from the outer edge of the scapula as far as the axillary line, then it turns downwards and forwards towards the præcordia. Sub-tubular breathing with crackles in dull region. Heart sounds feeble, with a faint soft systolic bruit at 4th left costal cartilage.

Sept. 26th.—Slept well last night, and did not vomit till after breakfast this morning, and then only to a small extent. B. regularly open.

Sept. 27th.—The vomiting returned during the night, and there was some sickness after breakfast, but none since dinner. P. 72. Tongue clear, some coolness of extremities and drowsiness.

Sept. 28th.—Was very sick during the night.

29th.—No sickness since yesterday morning. B. not open for three days, aspect languid and listless, evidently does not like to be disturbed, but answers questions correctly. P. 78, very thready and feeble.

30th.—Vomited a little after tea and supper last evening, and again after breakfast this morning; slept well; P. 70; still complains of tenderness and pressure over lower dorsal and upper lumbar spinas; B. not yet open.

Oct. 2nd.—Vomited scarcely at all yesterday, and passed a tolerably good night. Complains of some vertigo this morning. P. 70.

3rd.—Slept fairly, and complains of feeling very drowsy to-day; has again had severe vomiting. B. regularly open.

4th.—Vomited about 0j. of watery fluid during night.

7th.—Until last evening patient had enjoyed 36 hours freedom from nausea and vomiting; these symptoms returned, however, last night, and there has been some slight sickness this morning. P. 76.

10th.—Was sick again during the night, the vomitted matters containing a small quantity of blood. P. 82.

14th.—Yesterday morning patient coughed up a little blood which was quite bright in colour. Brandy ʒiij.

18th.—No sanguinous excretions yesterday, but again to-day to the extent of about ʒij.

20th.—Vomits bloody mucus daily, usually before breakfast. Eats her chop with relish. B. regular, if anything confined.

24th.—Pt.

27th.—Became worse again two days ago, and yesterday morning fancied she saw rats on her bed; indeed she still imagines she sees them running about; has been very sick this morning, and vomited blood as previously. Brandy ℥vi.

28th.—Patient continues in much the same state. P. 88.

2 p.m. P. 80. Surface cold, pupils small; some squinting still continues, and patient is incoherent and restless as before.

31st.—Continued better till yesterday at 3.30, when faintness came on and the breathing got rapid. This condition lasted about a quarter of an hour, was preceded by faintness and followed by increased talkativeness. During the night patient slept quietly, but at 7 a.m. complained of pain in the head, which was followed by faintness and hurried respiration. Breathing is now 28, P. 88, and very small; has vomited her egg. Tongue pale and bare, but tolerably moist. During examination the breathing became voluminous and rapid. B. regularly open. Strabismus continues at intervals.

Nov. 6th.—Since last report has gradually become less talkative, but still refers to some of her delusions, *e.g.*, that she has received presents from royalty, &c. Appetite has improved; there is still some squinting at times, but not so much. B. regular, no vomiting for the last few days. P. 80; R. 26.

15th.—Went on well from last report up to November 13th, when she complained of stiffness in all her joints, and began to squint again. Yesterday morning the catamenia appeared and patient was quite rational till 11 o'clock, but refused her food and afterwards became talkative and incoherent. For the last week she has had profuse discharge from the vagina. Last evening patient was quieter, but this morning she again became talkative and moreover *discontented*. P. 72, pupils contracted, some internal strabismus, says she wants to leave and refuses to put out her tongue; on the whole has much the same delirium as before, but is unusually ill-natured. Has 6 oz. brandy daily and takes her food well. B. regular.

Nov. 26th.—P. 80, R. 30 to 36, very irregular as regards extent, modus altered, inspiration and expiration equal with much upper sternal movement. Vomits considerably, vomited matter not tenacious, but occasionally streaked with blood; yesterday morning blood alone was brought up. T. natural, slight internal strabismus still remains, pupils slightly but equally contracted, no wandering, and patient takes her food pretty well.

Dec. 2nd.—P. 88, R. 26, very shallow; B. not open for two or three days. Vomited as usual last night and again after breakfast this morning, but not after dinner. Matters vomited abundant and like coffee grounds, not bloody. Brandy ℥ IV. Rept. Pil. podophyl.

Dec. 9th.—During the past week there has been a little wandering and patient has complained of sore throat. It is noticeable that there are now some pale hairs among the black ones. There is a laryngeal tenderness and no tonsillitis. Complains of increased feebleness and sacral pain. Catamenia did not appear at their proper time (viz., a week ago) and patient suffers from leucorrhœa.

January 7th, 1868.—10 a.m. Patient usually vomits once or twice a day, but the amount as well as the frequency varies greatly. B. somewhat confined. Tongue clear, appetite tolerably good. Considerable prostration is complained of, but there is no faintness now. P. 88, R. 36, T. 96. Urine rather thick, slightly opaline after boiling, and is not entirely cleared by NO_3H. Since last evening 7 o'clock 26 oz. have been passed.

On this day I carefully examined the patient, and arranged for the collection and transmission of the specimen of urine, which in the following record are numbered from 1 to 72.

1.—Jan. 8th, 1868.—From 10 a.m. yesterday till 10 a.m. to-day the bowels have not acted, and 21 oz. of urine have been passed, sp. gr. 1,015, strongly acid in reaction, and somewhat cloudy in appearance, which latter character is not entirely removed by heat and HNO_3. On microscopical examination a few

scales of epithelium from the urinary passages were observed, together with numerous multinuclear cells possessing the physical characters of pus.

Pulse 84. Resp. 40. Temp. 96·6. Respirations are somewhat irregular, and patient complains of much shortness of breath, but there has been no return of the vomiting since yesterday's report.

2.—Jan. 9th, 1868.—Was very faint at times yesterday and vomited frequently. Feels somewhat better this morning but still complains of shortness of breath. B. have acted once since last report, motion natural. Breath rather offensive. Urine acid, sp. gr. 1,019, still somewhat thick and cloudy, an appearance which is not entirely removed by heat and H NO. 33 oz. have been passed from 10 a.m. yesterday till 10 a.m. to-day. P. 88. R. 36-40. T. 98·2.

3.—Jan. 10th, 1868.—Did not sleep well during the night, but breath is not so short, and patient feels altogether better. The B. have not acted, nor has there been any vomiting since last report.

6.—Jan. 13th, 1868.—Slept well, and feels somewhat stronger this morning. Breath not quite so short, extremities rather cold, no return of vomiting. B. have not acted since last report. Urine acid, still cloudy in appearance, and not entirely cleared by heat and H NO. sp. gr. 1,020; 24 oz. passed from 10 a.m yesterday till 10 a.m. to-day. P. 84. R. 40–44. Temp. 97·2.

8.—Jan. 15th, 1868.—Slept well and feels better to-day; some vomiting after supper last evening, and again after breakfast this morning. B. open last night, motion hard and mixed with a small quantity of blood. Urine unaltered in character, acid, sp. gr. 1,017, cleared by heat and H NO_3; 26 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 92. R. 36–40. T. 98.

9.—Jan. 16th, 1868.—Slept badly, owing (she says) to shortness of breath. Vomited a little last evening. B. have not acted since last report. Complains of frontal headache with pains in limbs. Some nausea after breakfast this morning, but no vomiting, faintness, or vertigo. Urine acid, sp. gr. 1,021, still cloudy in appearance, and slightly opaline after heat and H NO_3; 22 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 88. R 44–48. Temp. 97·4.

10.—Jan. 17th, 1868.—Slept well, vomited a little last evening and was very short of breath, but feels much better this morning. B. open yesterday, and motion contained a small quantity of blood. Urine acid, sp. gr. 1,020, cleared by heat and H NO_3; 21 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. Examined microscopically it is found to contain a number of the same kind of puriform bodies noticed on the last occasion, together with epithelial cells of almost every size and shape; nothing at all resembling a renal cast was observed. P. 84; R. 36; T. 97·4.

15.—Jan. 22nd, 1868.—Did not sleep well as limbs appear to be more painful during the night. No return of vomiting, and patient says she feels much better this morning. B. have acted once since last report, and a good deal of blood was passed with the motion. Patient generally complains of headache and vertigo towards evening. Urine still cloudy, acid, sp. gr. 1,017. Opalescence slightly if at all affected by boiling, and not wholly removed by the subsequent addition of nitric acid; 24 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 88; R. 40; temp. 98·6.

16.—Jan. 23rd.—Slept well and is quite free from pain in limbs or elsewhere this morning; no return of vomiting; B. have not acted since last report. Urine acid, sp. gr. 1,020; general appearance as before, but cleared by heat and H NO_3; 27 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 84; R. 32, more regular; temp. 98·4.

22.—Jan. 29th.—Slept well; no return of vomiting, vertigo, or faintness, though still complaining of pain in limbs, especially at night. B. acted last evening; motion natural, and free from blood. Urine acid, sp. gr. 1,020; somewhat opalescent after heat and H NO_3; 33 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 88; R. 32–36; temp. 98.

23.—Jan. 30th.—Slept well; no return of sickness, vertigo, or faintness; B. have not acted since last report; patient says she feels better, being free from headache, though still complaining of pains in limbs. Urine

acid; sp. gr. 1,015, cleared by heat and H NO_3; 16 oz. passed during the 24 hours ending 10 a.m. this morning. P. 80; R. 32; temp. 98.

24.—Jan. 31st.—Did not rest so well last night, owing to pains in limbs and pricking sensation at præcordia, which still continues; no return of vomiting, vertigo, or faintness. B. open this morning, and some blood was passed with the motion. Urine acid, sp. gr., 1,020; some cloudiness after heat and H NO_3; 28 oz. have been passed from 10 a.m. yesterday till 10 a.m. to-day. Hands are not so cold as usual; tongue clean; appetite tolerably good. P. 92; R. 36–40; T. 98·4.

29.—Feb. 5th.—Did not sleep so well, owing to pain in left leg and ankle, no sickness, but patient says she felt faint and giddy last evening, with increased shortness of breath, which lasted the greater part of the night. B. open this morning, and a small quantity of blood was passed with motion. 25 oz. of urine have been passed during the 24 hours ending 10 a.m. to-day. P. 88. R. 48. Temp. 97·4.

30.—Feb. 6th.—Slept well, no sickness, faintness, &c., but still complains of constant pain in limbs, especially left leg and ankle. B. open this morning, motion slightly tinged with blood. Urine acid, sp. gr. 1,020. 26 oz. passed during the 24 hours ending 10 a.m. to-day. P. 80. R. 36. T. 96·2.

31.—Feb. 7th.—Slept tolerably well, and has had no return of sickness or vertigo, but felt a little faint last evening, pains in limbs still continue. B. acted this morning, and motion is slightly intermixed with blood. Urine acid, sp. gr. 1,013, tolerably clear after heat and H NO_3; 16 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 82. R. 28-32. Temp. 98·4.

32.—Feb. 8th.—Did not sleep quite so well, but complains chiefly of pain in limbs. B. open this morning, and motion mixed with blood. Urine acid, sp. gr. 1,019, quite clear after heat and H NO_3; 27 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 84. R. 40. Temp. 97.

33.—Feb. 9th.—Slept tolerably well, still complaining of pain in limbs, especially legs and ankles, which are considerably swollen, but do not "pit on pressure." B. not open since yesterday morning. Urine clear after heat and H NO_3; sp. gr. 1,020, acid, only 7 oz. passed from 10 a.m. yesterday till 10 a.m. to-day. P. 80. R. 32. T. 97·2.

38.—Feb. 14th.—Did not sleep quite so well, but says she feels better this morning. B. open last evening. Motion mixed with blood; no vertigo or faintness, but patient vomited once yesterday. Urine acid, sp. gr. 1,012 cleared by heat and H NO_3; 17 oz. passed during 24 hours ending 10 a.m. to-day. P. 88, R. 36–40, Temp. 97·6.

39.—Feb. 15th.—Slept well; no return of vomiting, vertigo, or faintness. Still complains of pain at back of neck and in legs, ankles remain swollen. B. not open since last report; *patient appears to be less discoloured than she was some few weeks back.* Urine acid, sp. gr. 1,021, clear after heat and H NO_3; 12 oz. passed. P. 80, R. 32, T. 97.

40.—Feb. 16th.—Feels much better; had a good night's sleep; was faint for about an hour yesterday afternoon; no vomiting or headache; legs and ankles still swollen and painful. B. open this morning; no blood in motion. Urine acid, sp. gr. 1,020, no albumen, 24 oz. passed. P. 88, R. 40, T. 98.

41.—Feb. 17th.—Vomited several times last evening and once again this morning, but slept fairly and does not feel any the worse. B. not open since last report; no vertigo or faintness. Urine acid, 1,024, clear after heat and H NO_3; 12 oz. passed from 10 a.m. yesterday till 10 a.m. to-day; P. 80, R. 36, T. 96·8.

42.—Feb. 18th.—Did not sleep during the night; vomited two or three times this morning, and complains of severe pain in limbs and at back of neck. B. not open since last report. Urine acid, sp. gr. 1,024, clear after heat and H NO_3; 14 oz. passed. P. 88, R. 44, Temp. 96.

Feb. 23rd.—Yesterday evening commenced vomiting, which continued during night. Bowels open three times after aperient. No urine saved. Very little sleep during night.

employed; to all others sulphuric acid was given. After 24 hours standing a deposit of a reddish brown or violet colour had collected, which was separated by filtration and washed until free from acid. This deposit never showed any appearance of crystals, so that if it contained any uric acid this must have been present in an amorphous state. The precipitate was first extracted with alcohol as long as this agent removed any coloured ingredients; the residue was thus free from hippuric acid and omicholine and uropittine, which, if present, must have been contained in the alcoholic solution. The residue was next extracted with dilute ammonia, in order to remove any uromelanine. Some brown matter was extracted, but found not to be uromelanine. The extract was quite free from uric acid. The residue left undissolved by ammonia was now treated with caustic potash to extract any uric acid. None could ever be obtained by the analysis of the urine of a single day, or of the combined urine of three or six days. The whole of the precipitates obtained from the whole of the urine from 12 entire days had to be united in order to obtain an unequivocal proof of the presence of uric acid; but the quantity which could be precipitated by acetic acid from the potash solution was only just large enough to serve for a microscopical test and a reaction with nitric acid. It was not feasible to weigh what remained as it was so small a quantity.

The urines Nos. 13 to 24 inclusive were treated like the first dozen specimens, the whole of the quantities being always employed. No trace of uric acid was found.

Nos. 25 to 36 similarly treated gave no evidence whatever of the presence of uric acid. Nos. 37 to 48 also contained no trace of uric acid. The ammoniacal and alcoholic extracts were in each case examined for uric acid, but as was to be expected were found quite free from it.

The acid liquid which had been filtered from the precipitate was mixed with sulphuric acid and subjected to distillation in a retort. By chemolysis a considerable precipitate was produced, which was isolated on the filter and washed. It appeared granular, and not resinous or semi-fluid. It was extracted with alcohol, which removed uropittine and omicholine, and left uromelanine behind on the filter. The latter was dried and weighed. The uropittine and omicholine were obtained by evaporation of the alcohol, dried in watch glasses, and weighed together. The quantities of uromelanine and uropittine and omicholine obtained are stated in the following table :—

No. of Urine.	Grammes of			
	Uromelanine.		Uropittine and Omicholine.	
	Total.	Per Day.	Total.	Per Day.
1 to 12 - -	0·7793	0·0649	1·0641	0·0886
13 to 24 - -	0·6685	0·0557	0·3070	0·0255
25 to 36 - -	0·9539	0·0794	0·4346	0·0362
37 to 48 - -	0·8186	0·0682	0·4780	0·0398

Conclusions.

From the above researches the following conclusions may be drawn :—

1. The urine in this case of bronzed skin disease or peculiar degeneration of the supra-renal glands contained during the first 12 days of observation only a minimum of uric acid. 2. During a continuous

period of 36 days the urine contained no uric acid whatever. 3. By chemolysis the urine yielded quantities of uromelanine, which amounted to about one-twelfth part of the quantity obtained from the urine of healthy persons during equal times. 4. The matters soluble in alcohol (omicholine and uropittine) obtained by chemolysis are far below the normal quantities, and do not stand in any uniform ratio to the uromelanine, the first 12 days yielding more matters soluble in alcohol than uromelanine, while the three periods of 12 days each which follow yield only about a third of the weight of the uromelanine in matters soluble in alcohol. If the fact of the irrationality of the quantity of these products should be well established, it would show that uromelanine on the one hand, and uropittine and omicholine on the other, cannot be derived from one and the same substance (urochrome). I hesitate, however, in forming that conclusion, because I suspect that uropittine is capable of transformation into uromelanine, and in that case the apparent irrationality of the results of the first 12 days might disappear on subsequent separate determination of the omicholine and omicholic acid.

General remarks on bronzed skin disease.

The above history of the case leads to some remarkable conclusions, which it is desirable to point out. 1. The brown deposit in the skin is the varying balance of a current account. It may increase or decrease. It decreased in the above case during two distinct periods. 2. The origin of the coloured matter is to be sought in the hematocrystalline, which while in the blood corpuscles undergoes a change unfitting the blood to pass through the capillaries. Hence the many hemorrhages and secretions on the one hand, the swellings and nervous symptoms on the other, and the deposits in the periphery, which become changed mainly under the influence of light. The further analysis of this case, and of similar ones, must be the work of a future time.

IX.—Calculi arising in the Urinary Bladder in Typhus.

The relaxation of the striated muscles which takes place in typhus fever frequently causes, particularly in old persons, great distension of the urinary bladder. This distension is not rarely overlooked, as there is no impediment to the flow of urine. It is also accompanied with involuntary passing of the urine, particularly in young persons. In children I have seen it pass into retention, with deposits forming in the bladder. It is most frequent amongst men in the later periods of life. The retention does not, so long as the urine has the acid concentrated character of the febrile stage, produce any phosphatic deposits; but during the anæmic state of recovery ammoniacal decomposition takes place, mucus is secreted, phosphates are deposited, and calculi are formed, which increase rapidly, and if not removed by operation cause kidney disease and death. The calculi under consideration, four in number, came from such a case. They had the size of walnuts, were white, hard, and contained each a cavity of the size of a pea in their interior. The cavities were empty when observed, which was after the calculi had been dry for some time. There is little doubt that the contents of these cavities were originally mucus, upon which the outer matter had been deposited. The mucus drying up left the cavities.

Analysis of one of the calculi.

Analysis of one of the Calculi.—The finely powdered stone was almost entirely soluble in dilute hydrochloric acid, the solution being only slightly opalescent. The filtered solution gave on addition of ammonia a precipitate easily soluble in dilute acetic acid. On addition of oxalate of ammonium a minute precipitate of oxalate of calcium was observed. On adding caustic potash to the powdered stone ammonia

to be turned to the left in order that you may look through the fluid as you do for the zero point.

The polarization of bodies changes very much according to the heat which they undergo. If dextrose is not heated it turns to about 116° of the circle, but when it is boiled once, or heated to near the boiling point, it only turns to 54°. This is the distinguishing property of of dextrose. Levulose, which turns to the left, does not show this change by heating. Now when these two varieties of sugar are present in wine, or in any artificial produce such as that which can be made by sulphuric acid from starch or cane sugar, the optical effect of the one hides the optical effect of the other if they are present in equal atomic proportions. If they are not present in equal atomic proportions then the one hides only a certain quantity of the other, and the optical effect is that only a portion of that which is in excess is perceived. For this reason, that the levulose reverts, as it were, the polarization of the dextrose, the mixture has been called "invert sugar," or "sucre interverti," which is the French name.

Immediate production of invert sugar.

We can in one instant produce the invert sugar by a very interesting experiment. This has been known since the year 1812, but it has been completely forgotten in all the discussions which have taken place as to the nature of yeast. We will take two parts of common white sugar, or cane sugar of the formula $C_{12}H_{22}O_{11}$, and mix them with one part of dry solid, so-called German yeast. The quantity of water which may be present in this yeast must be very small. It is hard, well-pressed yeast, and it does not even wet the paper in which it is contained. If we press the paper, and however much we press it, there is no mark of water upon it. We take a quantity of this, which we have detached from the lump, and weigh it off. We mix with that the double quantity of sugar by stirring them in a mortar. As if by magic the sugar is transformed into a syrup, the transformation of cane sugar into invert sugar is completed. I keep in the laboratory a quantity which I have made some time ago, and it is still a flowing liquid mass, a syrup. Now, when this is allowed to stand for only a very short time the proof that it is inverted sugar can be easily afforded. Cane sugar when treated with Fehling's solution does not give the reaction which consists in the reduction of the oxyide of copper contained in that solution. We will take a little of the cane sugar, and put it into this tube with a little of Fehling's solution. This consists of sulphate of copper to which some tartaric acid has been added, and the mixture has afterwards been made alkaline by the addition of an excess of caustic potash. Now when we heat this we obtain no reduction of the oxide of copper. The oxide of copper remains perfectly clear in the alkaline blue solution, but the moment we take a little of this inverted sugar, produced by the effect of yeast upon cane sugar, we obtain the reduction of the oxide of copper, and it is deposited in the form of yellow hydrated suboxide of copper; a sufficient proof that the cane sugar has actually been transformed into the inverted sugar.

Theory of yeast.

This is of the utmost importance, as directing the view which we may take of the nature of yeast. I consider this a fundamental experiment, which speaks against the assumption that the action of yeast in producing fermentation is due to organic life action. I believe it entirely upsets that idea, inasmuch as the transformation is instantaneous, and partakes of the nature of those actions which in chemistry we are in the habit of calling "contact actions." Moreover, it is not necessary, in order to produce the transformation, that we should use the yeast itself. We can take a watery extract of yeast, and *this*

extract of yeast will have the same effect, and almost in the same manner.

It is interesting to know that that kind of sugar which is excreted from the body in such large quantities in a particular disease is not this inverted sugar. Diabetic sugar consists mainly of grape or dextrose sugar. At present it is almost impossible to get any levulose at all out of diabetic urine, because it does not crystallize. It is a syrup, and by no means in our power can we make it solid, but it remains a liquid like glycerine. During the process of fermentation, on the other hand, we perceive the quantity of left-turning sugar to prevail over the other. In the beginning of fermentation there are two dextrose upon one levulose, and at the end of fermentation there are two levulose upon one dextrose. In the various stages intermediate between the beginning and the end of fermentation these proportions vary.

Diabetic sugar is dextrose.

Change of proportions of sugar during fermentation.

We are obliged to omit the consideration of other properties of these various sugars in order to come to their transformation. When the mixture of dextrose and levulose are subject to the action of yeast for any length of time, then a transformation takes place, which consists in the production of alcohol and other matters. Hitherto it was believed that sugar was directly transformed into nothing but alcohol, and carbonic acid :—

$$C_6 H_{12} O_6 = 2 (C_2 H_6 O) + 2 (CO_2)$$

This was believed to be the formula of the breaking up of the whole sugar, but we have found now that it is very different, and that of 100 parts of sugar only 94 pass into carbonic acid and alcohol, and that

3·5	are transformed into	glycerine,
0·5	„	succinic acid,
1·5	„	cellulose,
·5	„	carbonic acid,

in connexion with the glycerine and succinic acid. We have here, therefore, an important modification of our former ideas on the subject of fermentation.

We will for an instant see what is the action of yeast under these circumstances. We have seen that in the transformation of cane sugar it is instantaneous, and that the presence of the yeast-cell is not necessary, but that an extract, something coming from the yeast-cell, will do it. It is similar in the case of the transformation of sugar into alcohol. Here, however, the presence of the yeast cell is certainly necessary, but nevertheless the yeast-cell itself is not that which causes the transformation. It is something which comes from the yeast-cell which causes the transformation. The yeast-cell is supposed to be a kind of fungus the individuals of which multiply by growth.

Action of yeast.

Some suppose that these cells absorb the sugar, and then breaks it up in its interior and gives out alcohol and water. But this is a process which we cannot for an instant assume, because there is no benefit to the yeast done in that, and moreover the action is too rapid. It does not stand in any proportion to the amount of matter which any plant, or any living body, can consume in any given time, and any quantity of yeast, even a small quantity, may transform so vast an amount of sugar, that it is inconceivable that that plant should have used this amount of sugar as physiological food. Be that how it may, the result of this process is the production of alcohol.

Yeast cells.

Other sugars, mannite, dulcite, sorbine, lactose, including glycerine, cane sugar, starch, gum, and the dextrine which is found in the liver, or so-called hepatine, yield alcohol under certain influences, *e.g.*, water,

Various sugar-like substances yield alcohol.

chalk, and cheese, at a temperature not exceeding 60°. Alcohol, therefore, is by no means the exclusive product of levulose and dextrose, but other matters also produce it in small quantities. There is also another substance acetylene, $C_2 H_4$, which may be dissolved in sulphuric acid, and if this is afterwards mixed with water and distilled alcohol passes over. This has given rise to the proposition, that for the future a portion of the alcohol consumed by the public should be made from coal gas, which contains a small quantity of this gas. Should that proposition be realised the public may be supplied with light and with spirit from the same source.

Alcohol, description of.

Alcohol, in its isolated and distinct form, was discovered about the 12th century, and it was named by the Arabian physician Geber alcohol, that is, spirit. No doubt alcohol was known to the ancients, and it is not to be supposed that the famous Pramnic wine, of which Homer speaks, and which could be taken diluted with 20 measures of water, and yet make a man drunk, was anything short of 60 over-proof spirit. But the chemistry of alcohol has only in this century been more clearly evolved. We have learned that alcohol is a hydrated oxide of a radical which we call ethyl, and in that capacity is the representative of a series of bodies which are of the utmost importance in organic and theoretical chemistry, namely, of the alcohols. Ethylic alcohol may be written thus :—

$$\left.\begin{matrix} C_2 H_5 \\ H \end{matrix}\right\} O$$

Absolute alcohol is a liquid. It is colourless, it has an agreeable flavour, and burns when fire is set to it. It has also a burning taste, but the taste of pure alcohol is very agreeable indeed, and this is quite the reverse of what people ordinarily say, namely, that distilled alcohol has a nasty taste. It has a nasty taste, as ordinarily obtained, but this is due to the circumstance that certain products of decomposition are mixed with it, which, however, can be entirely removed, as Döbereiner has shown, by passing the distilled alcohol 50 times over animal charcoal. When it passes 50 times it is absolutely pure, and has the chemical properties and taste described.

Its specific gravity at zero is ·8095. At 14, however, which is the ordinary temperature, it is ·7982. It boils at 78 of the centigrade thermometer, under the pressure of 760 millimetres of the barometer. Even at the strongest cold, a temperature of — 100, it is only transformed into a thick fluid, but it is not solidified at any temperature or by any means. It can be burnt in a spirit lamp, and there comes little or no light from it. Alcohol attracts the moisture very rapidly, so quickly so that it may be compared to sulphuric acid in its power of so doing. With water it becomes warm and then contracts; 49·8 volumes of water, and 53·7 volumes of alcohol, which if they mixed without contraction would give 103·5, will contract so as to form 100.

Brandy obtained by distillation of wine.

When wine is distilled at a moderate heat a mixture of alcohol and water passes over which has about the foregoing composition, and this mixture is called brandy, but, whereas the art of distilling has become very much greater of late years, this brandy is not manufactured any more. In fact, it is an important element in trade that the articles to be sold and transported should be as concentrated as possible. Why should the brandy merchant in London carry three barrels from Montpelier to London when he can carry the same value of alcohol in two? Consequently the distiller transforms all his brandy into the strongest alcohol, namely, 60° over proof, and he does this by means of a particularly

adapted still. This mode is now generally adopted by the distillers of alcohol in all the great brandy-producing districts of France, Montpelier and Cognac in particular. There were last year 400,000 hogsheads of strong alcohol produced there, but the old method of producing brandy is almost out of use. The new method, then, gives a very strong alcohol, but it still contains some water. The chemist, therefore, in order to obtain alcohol pure, avails himself of various processes for the purpose of extracting it. The trade, who do it on a large scale, use burnt lime. Burnt lime is put into large vats, the alcohol is poured over, and the pure alcohol comes off, the water being retained in the lime. In the laboratory, however, we do it on a smaller scale, and use as a dehydrating agent the sulphate of copper. This salt is crystallised with a certain amount of water, and then is blue, but when we heat it it loses the water and becomes white. By shaking a sufficient quantity of this with strong alcohol the latter is made quite dry, and the copper salt becomes again blue or hydrated. We use this test also for the purpose of ascertaining whether the alcohol which we have been producing is anhydrous or not. If it be anhydrous the sulphate of copper will remain white; if it contains water the sulphate of copper will become blue. By means of large quantities of dehydrated sulphate of copper great quantities of dehydrated alcohol may be made.

Modes of obtaining concentrated and anhydrous alcohol.

Method of determining the Quantity of Alcohol in Fluids.—When we have a mixture of alcohol and water we obtain the specific gravity by means of an instrument called the hydrometer. In water only this hydrometer would stand at 1,000, but the lighter the fluid becomes the deeper it would sink, and in absolute alcohol it would sink to 798·2. If we have a mixture of alcohol and water, and we will determine the quantity of alcohol contained in it by the use of this hydrometer, we read the specific gravity, and from certain tables which we have we can tell the quantity per cent. by weight of alcohol contained in that fluid.

Method of determining quantity of alcohol in fluids.

Now this is the scientific method of doing it. But the law of England in this respect is different, and is distinguished from the practice of all continental nations in this, that it assumes a different standard, namely, a standard which is called "proof-spirit." By an Act of Parliament which was passed in the 56th year of the reign of George III. chapter 160, in the year 1816, it is enacted that the standard of all spirits upon which the excise shall levy taxes is to be a mixture of alcohol and water which shall weigh 12, while the same volume of distilled water shall weigh 13, all at a temperature of 51° Fahr.; or in the words of the Act: "And whereas since the passing of the said Acts an hydrometer "called Sykes's hydrometer has with great care been completed, and "has, by proper experiments made for that purpose, been ascertained "to denote as proof-spirit that which at the temperature of 51 degrees "by Fahrenheit's thermometer weighs exactly $\frac{12}{13}$ parts of an equal "measure of distilled water." How has the Legislature, or the traditions of this country, fallen upon this curious standard? This is a very singular story to tell. Before science had anything to do with buying and selling, it was usual to take a saucer and put a little gunpowder in it, and then pour a little of the spirit which was to be tested over it. Then the spirit was set fire to and burned, and at the conclusion of the combustion it was necessary that the gunpowder should also take fire. The spirit was called "proof" if it was sufficiently concentrated to cause the gunpowder to burn; for if the spirit contained so much water that at the end of the combustion the gunpowder was wet, then of course it did not burn. This, then, is the derivation of "proof-spirit," and according to this standard nearly all the spirit used in this

Proof-spirit.

History of "proof."

country is now bought and sold. Doubtless we shall in time conform to the method of other countries, so that also here a spirit shall be bought and sold according to its per-centage by weight in volume.

Discussion of medicinal properties of alcohol.

I have given a very explicit description of this particular substance, because I wish to go to the root of a certain question which has for a long time agitated the learned, and particularly physicians. Some years ago there was a great discussion on the question: Is alcohol food or physic? The great wonder was that while hundreds of men talked about it, none ever dreamed of setting to work to ascertain the solution of the question, until it struck three French learned men, namely, Lallemand, Perrin, and Duroy (the first one the late surgeon who died in the Mexican expedition), that they would investigate the question whether

French experiments.

alcohol when it was taken into the body was actually burned up, as Liebig had stated, or whether it was given out again unchanged. They caused a man who could consume a great quantity of alcohol to drink a certain quantity, and then they collected his urine, distilled it over, and to their very great surprise they found that the alcohol reappeared in the urine. They could burn it, they could show its presence, and straightway they ran to the conclusion that alcohol is not food. They said, "Alcohol is taken "into the body and goes again out of the body; it is true we have only "found a small quantity in the urine, but we must imagine that the lungs, "the skin, and the fæces admit of a very much greater portion being "exhaled, and therefore the fact that we have not found the whole does "not matter." In fact the question of quantity hardly entered their minds. They had found alcohol, and they straightway went to the conclusion that the alcohol is entirely secreted, and is a stimulant and not

New experiments.

a food. About two years ago this question engaged my attention, and I availed myself of an opportunity which I had of making an experiment on a large scale. 44 bottles of wine were drunk by 33 men during six hours of athletic sports, and their urine passed during six hours was collected under my observation for analysis. It was then subjected to 24 distillations, whereby with the aid of dehydration by copper sulphate a small quantity of alcohol was obtained weighing ten grammes. Then arose the remarkable question: In what proportion does the alcohol recovered stand to the alcohol consumed? and there we must again be guided by chemical analysis. The 44 bottles which were drunk by the 33 men contained 4,000 grammes of absolute alcohol, and there were, after dehydration, 10 grammes of alcohol obtained, the rest having been burned up in the system. Supposing that 10 grammes more passed out through the breath, the pores of the skin, &c., it would only give five grammes out of every thousand, or $\frac{1}{2}$ per cent., as the quantity which was left unused by the system. We have, therefore, here a direct proof that out of the whole quantity of alcohol drank only a quarter per cent. was excreted by the kidneys.

Subsequently going further, and in conjunction with my friend, Dr. Dupré, lecturer on chemistry to the Westminster Hospital, I made a great many smaller experiments in order to prove that the above was not an exceptional fact but the actual and invariable rule.

Dr. A. Dupré's experiments.

Experiment with Bordeaux Wine upon Six Men.—Six young men consumed 255 fluid ounces of red Bordeaux wine, containing 11,018 grains of absolute alcohol. The observation commenced at 1 o'clock p.m., and within an hour and a half, during which the men were engaged in sports and gymnastic exercises, four-fifths of the wine had been taken. All were more or less affected, two very strongly, which had not been the case in the previous experiment. Their urine was

collected till 5 p.m., and found to amount to 216 fluid ounces. It was four times distilled with the usual precautions. The final distillate amounted to 3 oz. The specific gravity of this distillate at 15·5° C. was 989·16, and therefore contained 6·32 per cent. of absolute alcohol by weight. A portion of the same distillate, when oxydised by potassium dichromate and sulphuric acid, gave an amount of acetic acid which was equivalent to six per cent. alcohol. Another portion of the distillate tested in Geissler's vaporimeter gave an indication leading to 7·3 per cent. alcohol, which would indicate that there was a small quantity of a substance more volatile than alcohol contained in the mixture.

Absolute alcohol taken in 255 oz. of wine = 11,088 grains.
„ „ obtained from 216 oz. of urine = 91·03.

Therefore of every 121·8 grains of alcohol taken 1 grain was reobtained from the urine. Of 100 absolute alcohol only 0·82, or a little more than four-fifths per cent. was recovered.

Comparison of the two foregoing experiments.

In my experiment on the large scale we could not be sure whether some very small quantity of the wine may not have been accidentally lost. But the foregoing experiment was minutely accurate in this respect. The quicker consumption in the second case may have made a difference, for less alcohol passes into the urine in proportion as we drink it in smaller quantities and at longer intervals; and I believe from further experiments that there is a limit, and that if we do not pass that limit no alcohol whatsoever, excepting the merest infinitesimal portion, passes into the urine, and that is 8, or 10, or 12 ounces of wine, namely, just that quantity which a reasonable man might drink with his dinner.

Mode of isolating alcohol from organic fluids.

Before continuing the account of the experiments on alcohol, I shall proceed to consider the manner in which it is isolated from organic liquids.

We will, as a pattern-fluid, take urine, which we have examined most frequently; but if it were necessary to analyse any other liquid of the human body, lymph, or any serous liquids, or watery extracts from any organ, in case we wanted to investigate the distribution of alcohol in the tissues, we would apply the same process to those watery extracts.

Distillation with tannic acid.

In the first instance we put them into a retort, and add a small quantity of tannic acid. This tannic acid is very necessary in order to prevent frothing. If we were to boil urine merely by itself without adding tannic acid, we would probably have bumping and frothing, and a small quantity of urine would pass over into the condenser, and we would lose our distillation. Having thus distilled the fluid once by itself, we proceed to re-distil it in order to remove from it any acid that may be present. We add a small quantity of caustic potash to the liquid, and after having given time for the reaction we proceed to distil it again. The effect of that process is that all the volatile acids are retained, while nothing but the alcohol and the ether present passes over. We have now already reduced the quantity of the fluid very much, and subject it now to a third distillation, this time with sulphuric acid, so that any volatile alkalies which may have been driven out in the first instance may not pass over but be retained. The third distillate, then, which is mostly only about one-eighth part of the original quantity, contains all the alcohol, no volatile acids, no volatile alkalies, and this produces a liquid which we now use for the test to be described.

Distillation with caustic alkali.

Distillation with sulphuric acid.

Chromic acid test for alcohol.

Alcohol when it is brought in contact with free chromic acid is so

much heated that it takes fire, and a kind of explosion takes place; but when we take a dilute solution of chromic acid, such as is produced by mixing dichromate of potash with sulphuric acid, we only obtain a slight reduction, and that is indicated by a transformation of the red colour of our test into a green colour. The sulphate of oxide of chromium is formed instead of the acid. We generally take one part of the dichromate to 300 of the sulphuric acid. We must take care to mix the distillate with two parts of sulphuric acid in the concentrated state, so that for the test we have considerably concentrated liquids. If we have not concentrated liquids we are liable to miss our test. If we pour a little of this into the mixture so that it sinks to the bottom, we perceive that where the one fluid touches the other there is a deep green colour, and then a ring of lighter green; and even if we have as little as one-fourth or one-tenth of a grain of alcohol in half an ounce of water, it will yet, by means of this test, be indicated. The test, therefore, is a very delicate one. Of course it is necessary that we should, before applying this test, have taken the precaution of distilling the fluid three times, as above detailed, otherwise the test will be fallacious on account of the organic matters not being alcohol decomposing the chromic acid in the same manner as alcohol.

Particulars of proceeding applied to urine.

The particulars of proceeding for determining alcohol in urine are the following: Test liquid, one part of dichromate of potash dissolved in 300 parts of sulphuric acid, that is, the solution which has already been described. If we make the reaction very nicely we can even discover the one-hundredth part of a grain of alcohol, but not in the quantity of half an ounce of fluid. Applied to the urine we need not generally take more than two ounces of urine. It is necessary that we should save labour as much as possible in these operations which have, in long researches, to be often repeated, and therefore it is well to know that two ounces will be a sufficient quantity to treat. Of that we distil off one-third under the precaution which I have mentioned as to tannic acid. Then of the distillate we draw off again one-third, so that we have one-sixth of the original; and of that again one-third, so that we have one-ninth of the original. During the operation of distillation, if we want to make quantitative researches it is necessary that we should close the whole of our apparatus so as to be air-tight, and we should provide the receiver with a mercurial valve.

Delicacy of test.

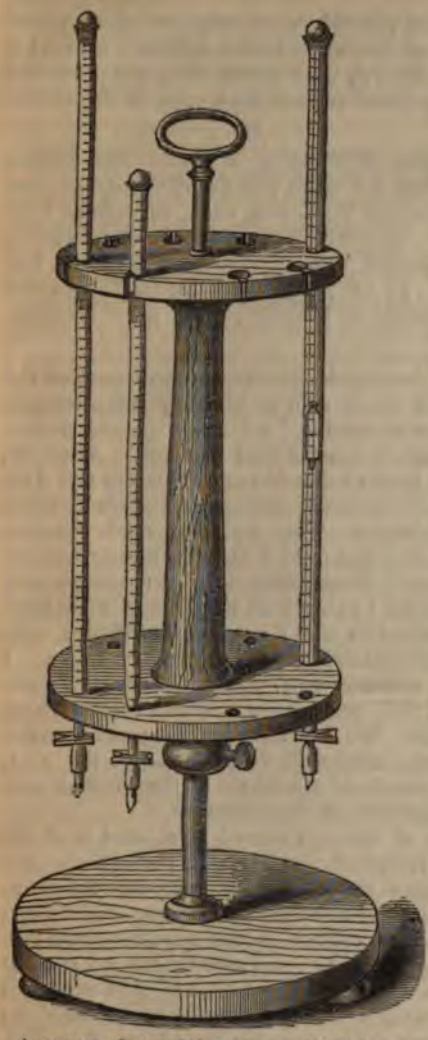
Normal urine when tested gives no reaction for alcohol under any circumstances unless alcohol has previously been taken. If we add one-tenth grain of absolute alcohol to two ounces of urine, and afterwards distil, we get a reaction very distinctly, which shows the great delicacy of the test. Only one source of fallacy exists with regard to it, and that is, that a small quantity of ether of some kind or other may be present, and that ether would, of course, in the process which we shall have to consider presently, be decomposed, and also be transformed into acetic acid and increase it. It is possible, for example, when we drink Greek wines, which contain a great quantity of aldehyde, that a quantity of that passes into our urine. There is not much physiological value in that fact, but nevertheless it is to be considered.

Dr. Dupré's new method of determining small quantities of alcohol.

Now, then, we have a quantity of alcohol so obtained from urine, and we want to determine how much it is. The tenth of a grain of alcohol in two ounces of water would not admit of any specific gravity determination. It would not be possible to immerse any instrument, or to put that small quantity on a balance sufficiently fine to determine that, and therefore it is necessary to take a somewhat circuitous but

still a quite certain route, and that is, we take the distillates and oxidise the alcohol therein contained to acetic acid, and determine it by quantitative analysis, or even make a salt of it. Alcohol does not combine with any other body; we cannot increase its weight; we cannot retain it in any way; whereas acetic acid combines with many, and owing to this property the quantity of the acid can be very easily determined, even in solutions. This is done in the following way: We enclose the distillate with a certain quantity of the dichromate and sulphuric acid mixture in a flask, and stop it air-tight with an india-rubber stopper, and tie it down well by means of wire. This bottle we now heat for two hours in a water-bath at a certain temperature, never amounting to boiling. During that time the whole of the alcohol is transformed into acetic acid. Then when we have oxydised the alcohol we have to distil that over, and for that purpose it is only necessary to distil the mixture down to one half in the same bath in which we have got the acetic acid. We now determine the acidity of our distillate by applying to it a caustic soda solution, a so-called standard solution, a solution of which we know the strength, and so ascertain the amount of acetic acid contained in the distillate. According to this plan the following experiments were made. The experiments on the large scale mentioned above were not so made, but resulted in the isolation of the pure absolute alcohol.

Transformation of alcohol into acetic acid.



Apparatus for applying Standard Solutions.

Experiment with Rhine Wine upon a Man.—The subject of the experiment voided all urine at 10.30 a.m., and took 10 oz. of Rhine wine containing 1 oz. by measure of absolute alcohol. While the urine passed at 10.30 had yielded no tests indicating the presence of alcohol,

Experiment with Rhine wine upon a man.

at 11.30 a.m.	2 oz.	of urine passed	contained alcohol.
at 12.30 p.m.	1¾ oz.	ditto	ditto
at 1.30 p.m.	1½ oz.	,,	
at 2.30 p.m.	1 oz.	,,	contained no alcohol.
at 3.30 p.m.	¾ oz.	,,	
at 4·30 p.m.	¼ oz.	,,	
at 5.30 p.m.	3 oz.	(2 oz. distilled)	

The urine from 5.30 p.m. to 9.30 a.m. of the next day, 13 oz. in all, was distilled repeatedly until it amounted at last to ½ oz.; it contained no alcohol.

When the reactions which were yielded by the urine which contained alcohol were compared to those of fluids containing a known amount or alcohol, it was estimated that less than $\frac{1}{10}$ (one-tenth) of a grain of alcohol was present in all. In this case, therefore, less than $\frac{1}{4000}$ of the alcohol taken appeared in the urine.

Experiment with Bordeaux wine upon a man.

Experiment with Red Bordeaux Wine upon a Man.—The subject emptied his bladder at 11 a.m., and the urine was found to be free from alcohol. He then drank 8 oz. of red Bordeaux wine, containing 1 oz. by measure of absolute alcohol. The urine passed at 12 o'clock (noon) measured 5½ oz. and contained alcohol, but only the slightest trace, less than $\frac{1}{3000}$ of the whole taken. 2½ oz. passed at 1 p.m.; 2 oz. passed at 2; 1 oz. passed at 3; 2 oz. passed at 4 o'clock p.m., were all quite free from alcohol.

Experiment with rum upon a man.

Experiment with Rum upon a healthy Man.—The subject emptied the bladder at 11 o'clock p.m., took 2 oz. of rum of almost proof strength, and went to bed half an hour afterwards. All urine passed during 12 hours succeeding was collected, and amounted to 13 oz. After the addition of a little sulphuric acid it was subjected to distillation and 5 oz. of distillate were obtained. This was made alkaline and again distilled until 1¼ oz. of distillate were obtained. This was again made alkaline and 1 oz. of fluid drawn off. Of this last fluid 1 cubic centimetre mixed with the chromic acid test gave only the slightest possible reduction, and that only after some time. In order to obtain an estimate of some kind of the quantity of alcohol contained in the 1 oz. last distillate, 1 cub. centimetre of absolute alcohol was mixed with 2,000 CC. of water. 1 cub. cent. of this mixture added to 1 cub. cent. of chromic acid test gave a strong reduction, and even ½ cub. cent. gave a slight effect, which became more marked on standing. We may therefore estimate that the last distillate contained less than 1 alcohol in 2,000 water, or the 1 oz. less than ⅓ of a grain. Consequently of the whole of the alcohol consumed less than $\frac{1}{2000}$th part reappeared in the excretion.

Analysis of urine in regard to alcohol of great importance in study of treatment of acute diseases.

The question of the analysis of urine in regard to alcohol is of the utmost practical importance in reference to the treatment of fever and acute diseases, in fact any diseases whatever. Of late years the practice has arisen of treating diseases, particularly fevers, with large quantities of alcohol. This practice was mainly introduced by the late Dr. Todd, of King's College Hospital. In some cases there 30 and 40 ounces of brandy were consumed by a single patient in 24 hours, and according to the records which were kept, those persons experienced no disadvantage whatever from taking those enormous quantities of alcohol. 20 ounces of absolute alcohol would kill any ordinary healthy person if he drank it in 24 hours, but with these fever patients the higher their fever the more alcohol could they consume, and apparently without any disadvantage to themselves, but rather the contrary. Now there came, of course, the question, What becomes of this alcohol? Is it excreted? Is it used merely as chloroform is, only to produce anæsthesia, and does it then go away again or not? and Dr. Dupré therefore made the experiment here related.

Experiments with wine and brandy upon a case of typhus fever.

Experiments with Wine and Brandy upon a case of Typhus Fever.—The patient took 6 oz of. brandy daily, and on some days additional quantities of wine.

First day of exp.—Total urine from 24 hours 20 oz.; distilled with acid; alkali and acid, as in the experiment with rum. 1 oz. of final distillate contained less than ⅓ grain of alcohol.

Second day.—6 oz. of brandy and 18½ oz. of wine. The last distillate of 1 oz. contained decidedly less than $\frac{1}{2}$, a little more than $\frac{1}{3}$ of a grain of alcohol.

Third day.—6 oz. of brandy and 15½ oz. of wine. The last distillate of 1 oz. contained less than $\frac{1}{4}$ grain of alcohol.

Fourth day.—6 oz. of brandy only. The final distillate from 620 cub. cent. of urine, amounting to 1 oz., contained less than $\frac{1}{8}$, a little more than $\frac{1}{4}$ of a grain of alcohol.

Fifth day.—6 oz. of brandy only. The last distillate from 630 cub. cent. of urine contained less than $\frac{1}{8}$, a little more than $\frac{1}{10}$ of a grain of absolute alcohol.

Sixth day.—6 oz. of brandy only. The last distillate was oxydized by chromic acid, and the acetic acid produced was estimated; it indicated less than $\frac{1}{2}$ grain of alcohol.

Seventh day.—6 oz. of brandy. The fæces were examined exactly like the urine, and less than $\frac{1}{10}$ grain of alcohol found to be present. $\frac{1}{2}$ grain of alcohol was added to 18 oz. of water and distilled as the urine in the foregoing experiment. The last distillate of 1 oz. contained more than $\frac{1}{3}$, only a little less than $\frac{1}{2}$ grain of absolute alcohol. Controlling experiment upon water.

Now we see here the quantities of alcohol which proceed from the typhus body are not larger than those which would pass from an ordinary healthy person; consequently it was quite clear that these enormous quantities of alcohol taken are consumed in the economy, are oxidised. Whether they are beneficially consumed or otherwise must remain for future research to determine; but I have not the slightest doubt, from my own experience, that the giving to typhus patients considerable quantities of wines and alcoholic drinks, not concentrated, but refreshing, stimulating, good, well-tasting drinks, containing not much sugar, is one of the most beneficial things that can be done. Conclusion.

These researches might be multiplied. In fact they ought to be spread over a much larger number of cases.

We will now consider, for a short time, the physiological effects of alcohol, in order to make our case complete. It is found that alcohol, when taken in large quantities, before it produces collapse and intoxication lowers the temperature of the body considerably. Experiments have been made upon drunkards, or at least people who are in the habit of drinking a great deal, and getting what is popularly known as "mellow." If we take such a man, and let him drink as much as he can and likes, we find that his temperature when he is in that state is considerably decreased, even by one or two degrees. In ordinary persons who take the quantity of alcohol which I propose to make the standard, namely, two ounces in a given time, no lowering of the temperature takes place, but rather a slight increase, a quarter of a degree or so, but not more. Physiological effects of alcohol. Drunkenness diminishes temperature of body. Moderate quantities of alcohol warm the body.

There are yet some reactions of alcohol which should be mentioned. A reaction of alcohol which we make use of is its property of attracting water, by means of which it precipitates albumen. When we mix the alcohol with white of egg albumen is precipitated. For a time this precipitate is soluble in water, but after a certain time it is no longer so. The anatomical specimens which we have in our museums are all preserved in that way. The water is withdrawn from them by the alcohol, they are repeatedly steeped, and ultimately they are kept in alcohol almost unchangeable. Alcohol is also made use of for the preservation of many kinds of fruit, such as cherries. It is a very curious fact that the pulp of fruit has a very great power of retaining alcohol, so much so that in the making of wines in France it is very well known that there is more alcohol contained in the marc, Preserving power of alcohol. Fruit preserved in alcohol. Cherry brandy.

or the residue of the stalks, and the husks of the grapes, than there is in the wine which flows out, and that it is necessary to press the mure very strongly in order to obtain the alcohol which is in the mixture of mure and wine. And so when we steep pears, or apricots, or peaches, or any of those many fruits which are preserved in France, we always find that they attract a large quantity of spirit, and the liquid which we press out of the fruit itself is much stronger in respect to alcohol than the liquid in which it is suspended. Thus in eating brandy cherries we eat more concentrated brandy than we would drink if we were to drink the liquid in which they are kept.

Large amount of alcohol consumed in England.

I will for a moment consider the large quantities of alcohol which are consumed in this country. In England there are annually consumed many millions of barrels of beer. Wine is not comparatively much drunk in this country, but brandy is in enormous quantities. The tax upon alcohol as a whole realizes more than 10,000,000*l.* of revenue, and we can see, therefore, that alcohol is drunk by almost the whole of the population, with no very great exception. There is no doubt that by this practice of drinking alcohol in large quantities, particularly what are called "raw spirits," many diseases are engendered, and in London in particular a vast amount of the disease which shows itself in the hospitals is caused by the consumption of enormous quantities of porter on the part of the labouring classes, which may range up to 16 pints a day. If we observe labourers at work, in building houses, for example, we sometimes see them throughout the day drinking porter by the half pint or pint, and the potman comes round from the public-house every hour or half hour with fresh supplies; and this independently of what the labourer will drink at the public-house after his work is over. These cases furnish the staple of particular forms of kidney disease; and the habit of drinking large quantities of spirits and beer is to be deprecated as highly dangerous and objectionable. But when from this the conclusion is drawn that alcohol ought altogether to be abandoned, and that we all ought to do without any alcohol, I must say that that is one of the most overstrained propositions that could be made. Alcohol, when we have worked and are fatigued, is a great restorative and stimulant and food, and one of the greatest necessities of human life; and perhaps there has been no time and no nation in which some kind of alcohol has not been used, and mostly in the largest number of cases beneficially. If we do not exaggerate the quantity which we introduce into our stomach we will never have reason to fear that our kidneys will be damaged by that quantity of alcohol which will pass through them and be excreted.

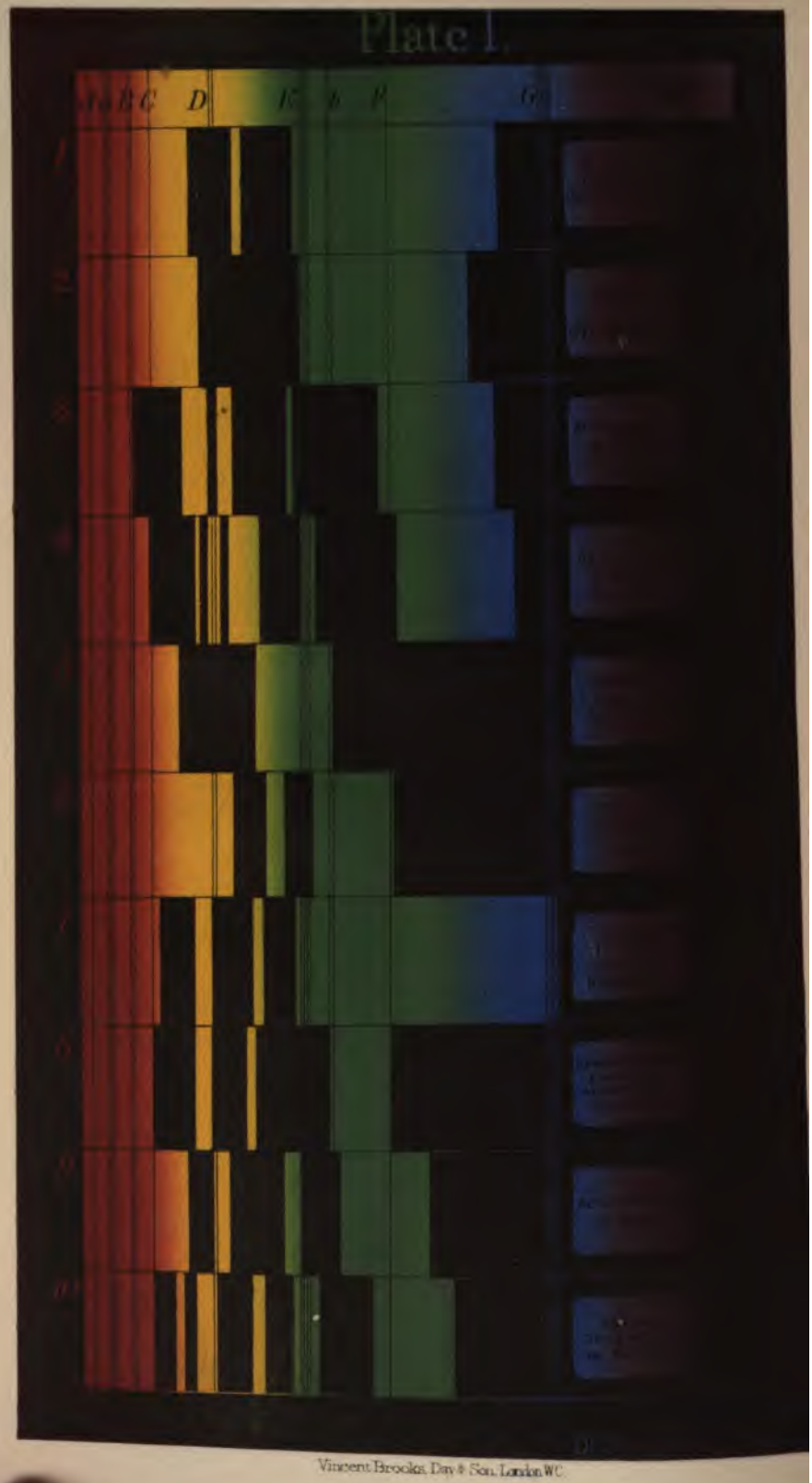
Alcohol is a beneficial stimulant and restorative.

D

Explanation of Plate I.

The top spectrum represents the continuous spectrum of the sun, with the main sun-lines indicated by Fraunhofer's letters. The dispersion is about equal to that of a sulphide of carbon prism of a refracting angle of 60 degrees.

1. Hematocrystalline in the oxydised state, being the spectrum of arterial blood, plainly termed blood-spectrum.—(See p. 197.)
2. Hematocrystalline in the reduced or deoxydised state, being spectrum of venous blood.—(See p. 198.)
3. Acid hematine in ether or four-banded hematine spectrum.—(See p. 201.)
4. Acid hematine in alcohol, or five-banded hematine spectrum.—(See p. 200.)
5. Alkaline hematine in alcohol spectrum.—(See p. 202.)
6. Reduced alkaline hematine in water spectrum.—(See p. 203.)
7. Hematocrystalline changed by hydrothion.—(See p. 199.)
8. Solution of cruor treated with alcohol and caustic ammonia.—(See p. 200.)
9. Acid sulphate of cruentine in water. (See p. 204.)
10. Neutral cruentine sulphate in alcohol, or five-banded cruentine.—(See p. 205.)



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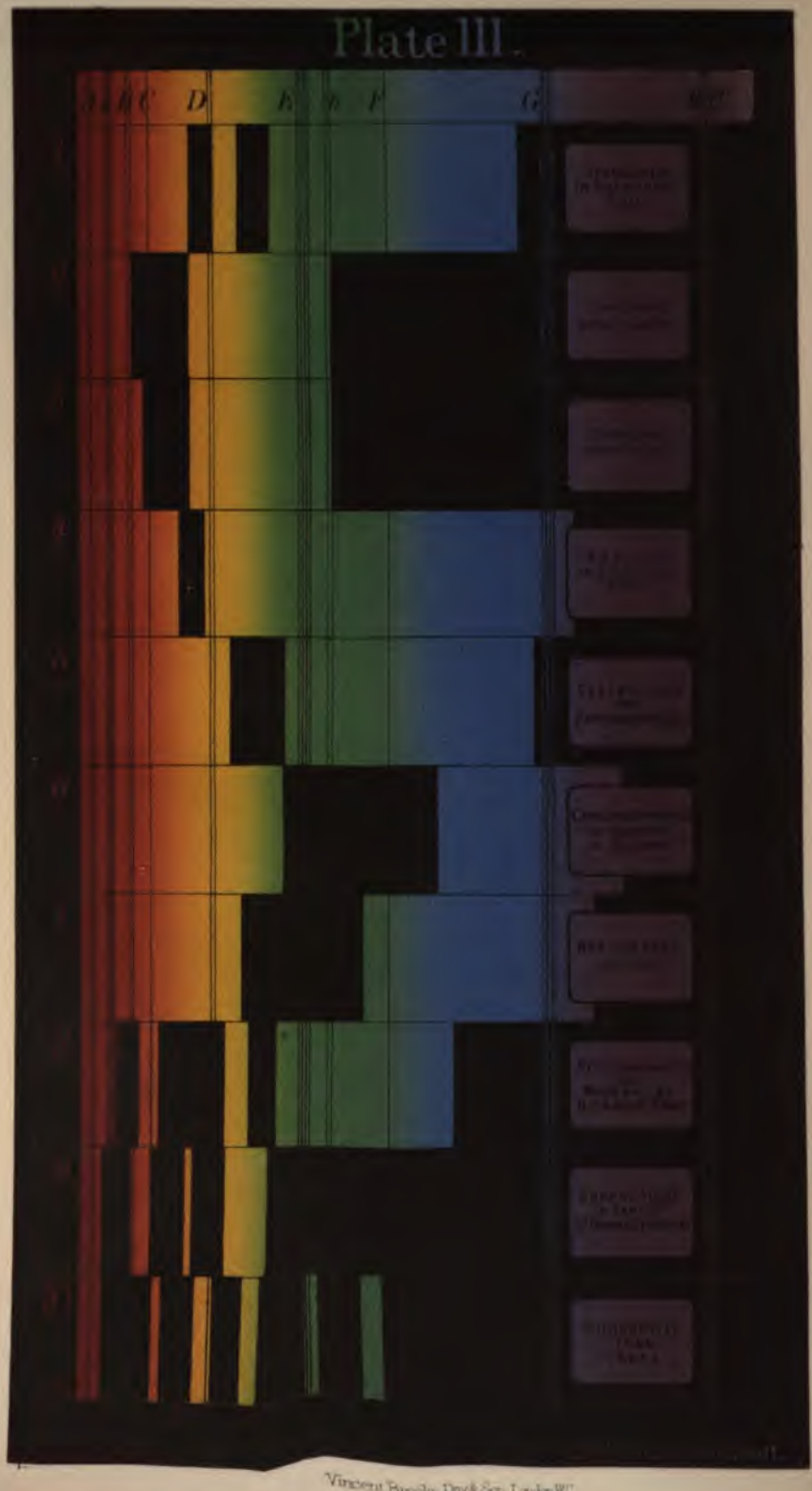

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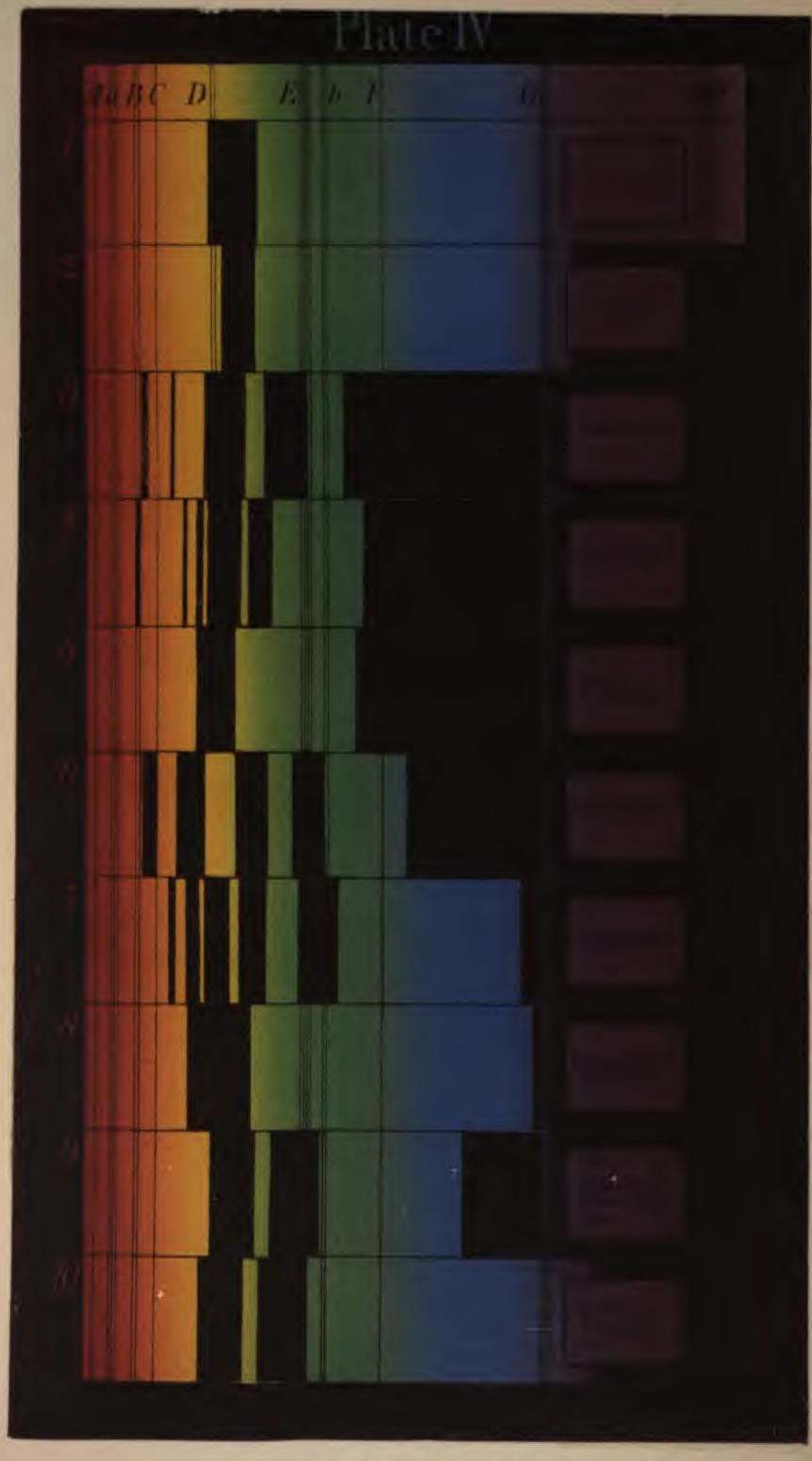
Explanation of Plate III.

Solar spectrum with principal lines and letters.

1. Stercorine in sulphuric acid.—(See p. 158.)
2. Choleraic urocyanine in alcohol.—(See p. 248.)
3. Choleraic urorubine in alcohol.—(See p. 248.)
4. Vitelline or lecithine from yelks of eggs in sulphuric acid.—(See p. 161.)
5. Cerebric acid and Pettenkofer's test.—(See p. 161.)
6. Chromatophores of lobster ; alcoholic extract.—(See p. 191.)
7. Red currant juice.—(See p. 191.)
8. Green alcohol extract of red algæ growing on macerating diseased bone.—(See p. 191, where there is also a diagram of the spectrum of the red algæ themselves.)
9. Alcohol extract of green cellular algæ in lake of St. Thomas's Hospital.—(See p. 193.)
10. Alcoholic solution of chlorophyll from grass.—(See p. 193.)



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Explanation of Plate IV.

Solar spectrum with principal lines and letters.

1. Omicholine in ether.—(See p. 247.)
2. Omicholic acid in ether.—(See p. 247.)
3. Fluopittine in alcohol.—(See p. 214.)
4. Cholonematine in ether.—(See p. 229.)
5. Bovifuscopittine in alcohol.—(See p. 230.)
6. Muscoprasine in alcohol.—(See p. 331.)
7. Ethochlorine in ether.—(See p. 231.)
8. Bile and Pettenkofer's test.—(See p. 232.)
9. Red feather of Cape Lory (Turacus albo-crystatus.)—(See p. 197, footnote.)
10. Alkaline solution of the pigment of the red feather of this bird.—(See p. 197, footnote.)

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Explanation of Plate V.

Section of solar spectrum with lines and letters.

Cs.—Spectrum of cæsium; 13 lines are represented, of which the red one, in the ultra-red heat region, is most remarkable and most difficult to observe.—(See p. 178.)

Rb.—Rubidium. (See p. 178.) All ten lines are represented. In this and the cæsium spectrum the continuous portion of light similar to that which appears in the potassium spectrum has not been represented, in order to fully define the lines in yellow and green.

K.—Potassium. Two bands, one red, one violet and portion of continuous spectrum. A feeble red luminosity at *a* has been omitted. —(See p. 178.)

Na.—Sodium. (See p. 177.)

Li.—Lithium. (See p. 178.)

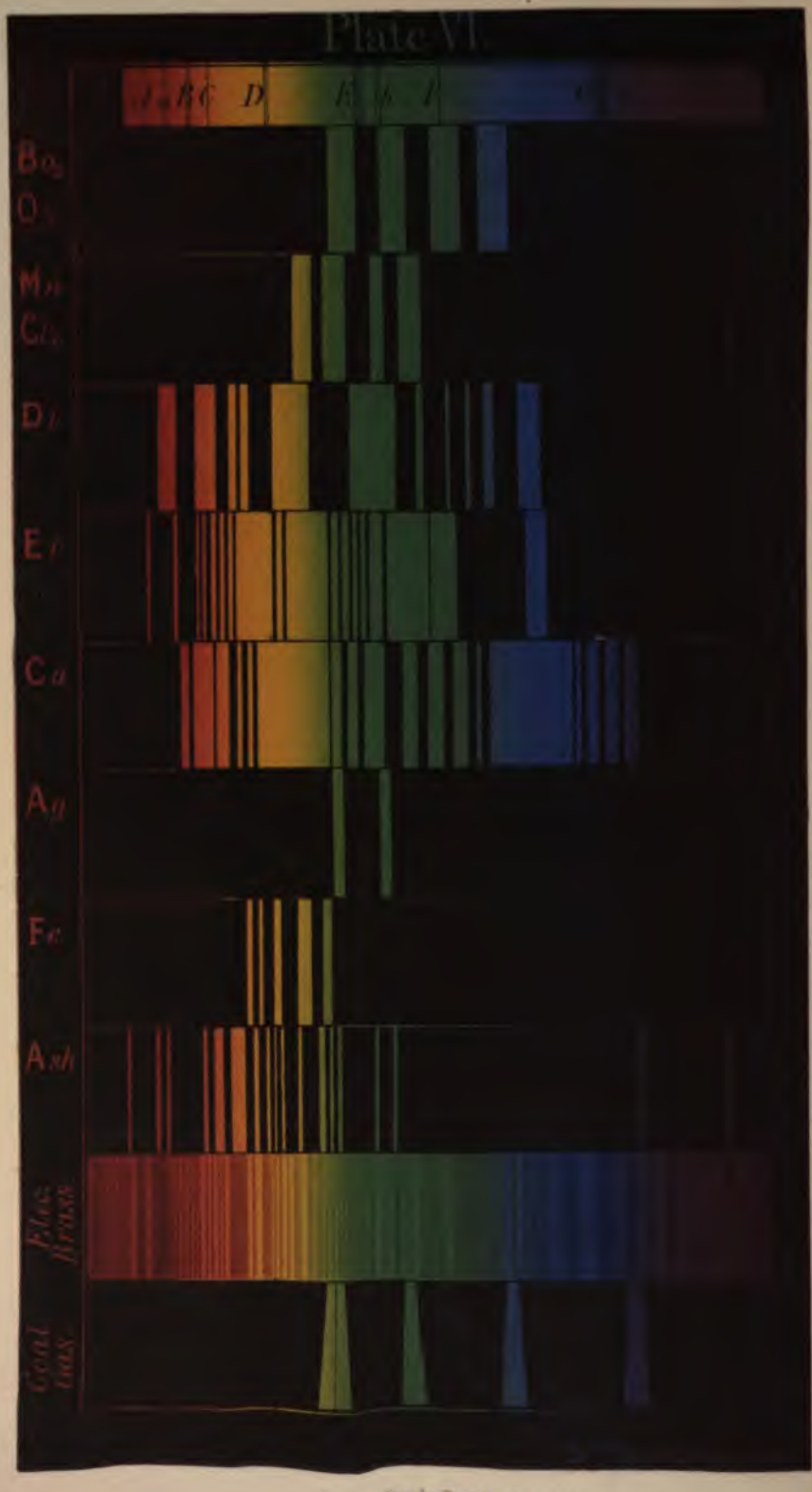
Sr.—Strontium. (See p. 179.) Its eight bands are all represented.

Ca.—Calcium. (See p. 179.) Of the nine calcium bands only eight are represented. A feeble line close to one of the four narrow lines in the middle has been omitted.

Ba.—Barium. (See p. 179.) Of the 15 barium lines only 11 have been represented, as being the best definable and easily seen with every good spectroscope.

Tl.—Thallium. (See p. 180.)

In.—Indium. (See p. 180.) Name derived from its blue coloured vapour and blue and violet band.



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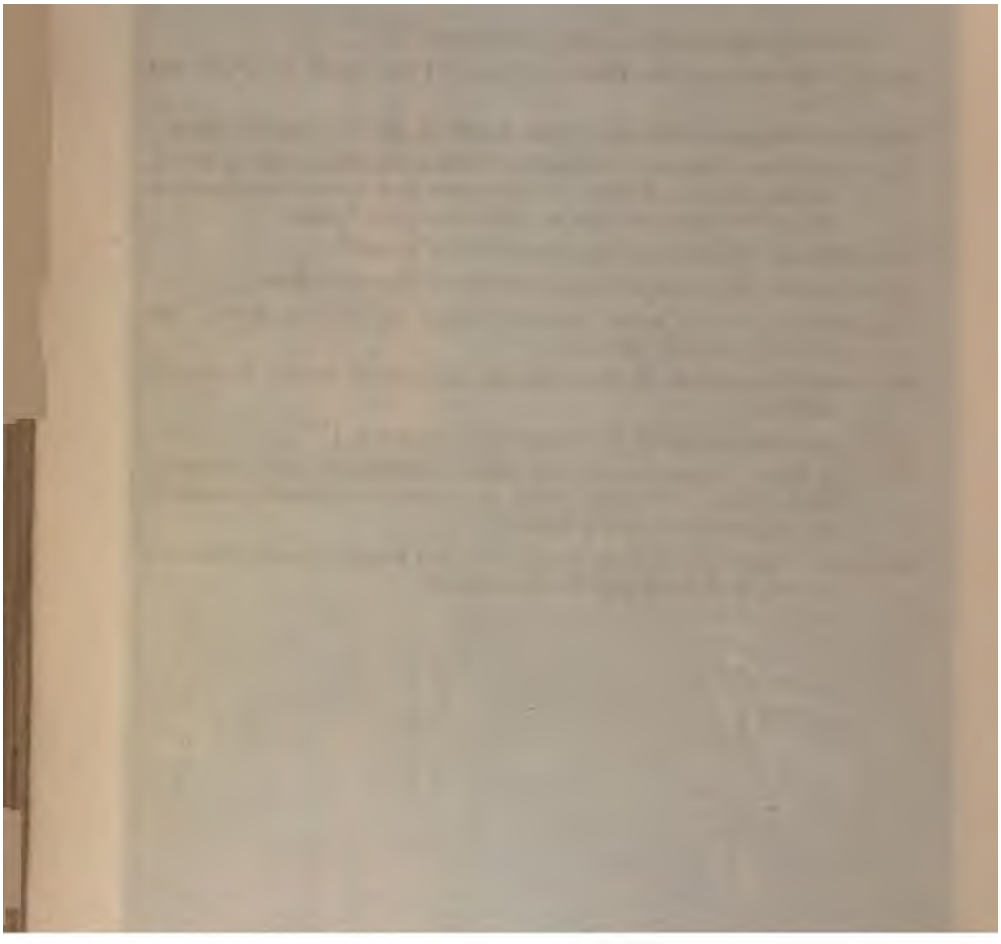

Explanation of Plate VI.

Section of solar spectrum, lines and letters.

Bo_2O_3.—Boracic acid in Bunsen's flame. Four bands in green and blue.

$Mn\,Cl_6$—Manganese chloride. Four bands in green, a line in violet.

Di.—Didymium. Series of 11 bands of different widths, situated in red, yellow, green, and blue. In solutions and crystals of didymium salts these bands are seen as dark absorption bands.

Er.—Erbium. Spectrum of a glowing bead of its earth.

Cu.—Copper. Spectrum of copper chloride in Bunsen's flame.

Ag.—Silver. Two principal bands of silver by electric spark; the electric spectrum omitted.

Fe.—Iron. Five bands of iron chloride, as evolved by arc in electric lantern.

Ash.—Spectrum of ash of the human body.—(See p. 177.)

Electric Brass.—Spectrum of the electric induction spark between brass poles. Metallic lines as much as possible omitted. Atmospheric and hydric lines.

Coal gas.—Spectrum of inner cone of coal gas burning from a Bunsen's burner, with blow pipe fixed in centre.

Note to the Maps which illustrate Dr. Buchanan's Report.

THE object of these maps is to convey to the eye a general notion of the position and boundaries of each district, and of its broad geological features. They have been printed from an electrotype plate of the Index Map of the Ordnance Survey, supplied by that Survey. The district boundaries on the one map, and the geological lines on the other, have been obtained by photographic reductions from larger maps, by Mr. J. B. Jordan, of the Mining Record Office. The geological lines, which have been engraved by Mr. J. W. Lowry, show with accuracy and considerable detail the distribution of the surface geology. The colouring has been done by Mr. W. Bone, the colourist of the Geological Survey. Mr. Whitaker has kindly superintended the preparation of this map, using unpublished as well as published sheets of the Geological Survey. He and Mr. Topley have added a very useful section, exhibiting the relation of the several formations to each other.

The map of the Geological Survey that was actually employed in the preparation of the report measures, for the area here represented, about 110 by 53 inches, or upwards of 40 square feet—a scale large enough to show particular houses. It is evident that the little geological map here given does not pretend to furnish any authority for the statements of the report; and that from its scale many points cannot be demonstrated upon it.

Thus (1) Narrow tracts of alluvium along streams are not shown. (2) Brickearth is not separated from gravel. (3) The divisions of the Bagshot Beds are not given—they are of small moment. (4) The divisions of the Lower Greensand are not shown, and what is more important, (5) The divisions of the Hastings Beds into sands and clays is not made—these divisions are made in nature by no long and well-defined boundaries, but by very irregular and multitudinous lines which could not be exhibited on this small map. (6) Faults are not marked, and (7) Of the formations that are shown, very small detached patches are, from the necessity of the case, omitted.

What the geological map does profess to exhibit, viz., the distribution of the main formations, of the broader tracts of alluvium, and of the more important surface coverings of gravel and the like, it exhibits in a very exact and reliable way. Its only known inaccuracy is that, in a small area of the north-east of Kent, and again over a large tract in the neighbourhood of Chichester, there are certain gravels which are not shown by stippling. These gravels are only mapped in certain unpublished documents of the Geological Survey, and time did not permit of their being copied, reduced, and engraved. But they have all been carefully considered in the statements of the report.—G. B.

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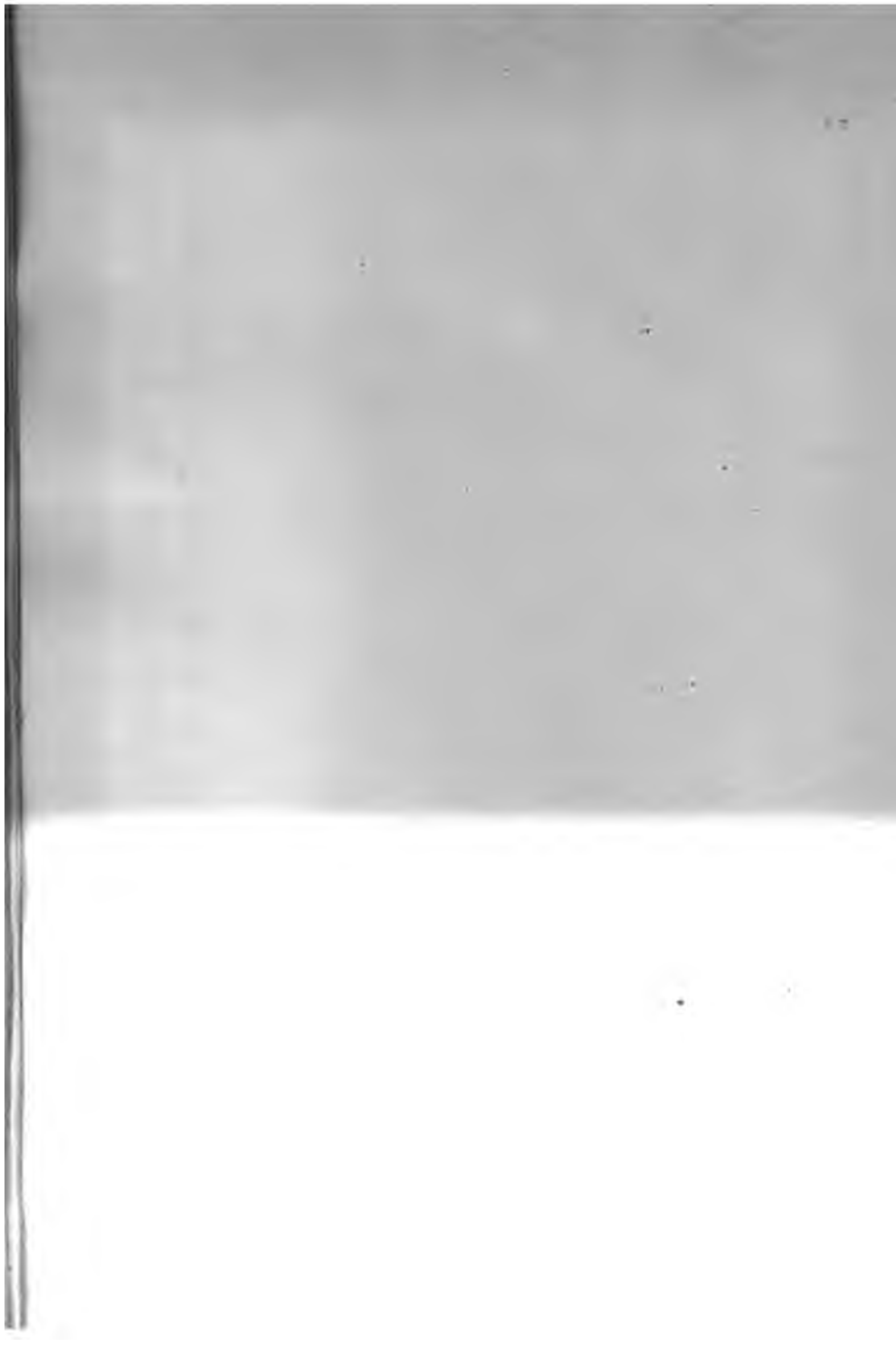
For Her Majesty's Stationery Office.

A

EACHY HEAD

Boundary
Kent



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